Technical Report 1000

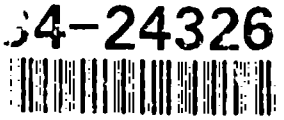
Information Management Performance of Future Platoon Leaders: An Initial Investigation

Carl W. Lickteig
U.S. Army Research Institute

Cathy D. Emery
University of Louisville

June 1994

United States Army Research Institute for the Behavioral and Social Sciences



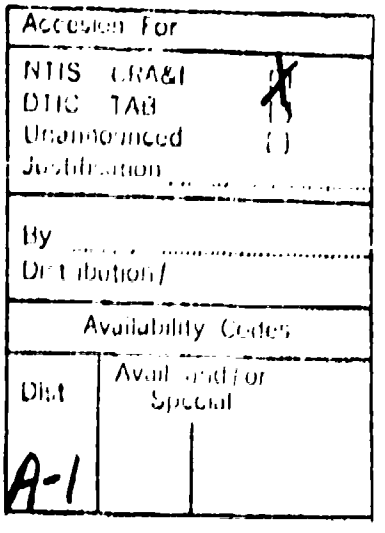
U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Director

Technical review by

Donald M. Kristiansen
Margaret S. Salter



NOTICES

DISTRIBUTION: Primary distribution of this report has been made by ARI. Please address correspondence concerning distribution of reports to: U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: PERI-POX, 5001 Eisenhower Ave., Alexandria, Virginia 22333-5600.

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1 AGENCY USE ONLY (Leave blank)	2 REPORT DATE	3 REPORT TYPE AND DATES COVERED
	1994, June	Final Sep 90 - Jul 93

4 TITLE AND SUBTITLE
Information Management Performance of Future Platoon Leaders: An Initial Investigation

5 FUNDING NUMBERS
63007A
795
3206
H02

6 AUTHOR(S)
Lickteig, Carl W. (ARI); Emery, Cathy D. (University of Louisville)

7 PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
Field Unit at Fort Knox
Fort Knox, KY 40121-5620

8 PERFORMING ORGANIZATION REPORT NUMBER
--

9 SPONSORING MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
ATTN: PERI-IK
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

10 SPONSORING MONITORING AGENCY REPORT NUMBER
ARI Technical Report 1000

11 SUPPLEMENTARY NOTES
Cathy Emery is a graduate student at the University of Louisville who worked as a Consortium Fellow at the U.S. Army Research Institute Fort Knox Field Unit.

12a DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b DISTRIBUTION CODE
--

13 ABSTRACT *(Maximum 200 words)*

As the Army moves toward vehicle-based automated command and control (C^2) systems, small unit commanders face new challenges in managing battlefield information. This report evaluates the information management performance of platoon leaders equipped with a future C^2 system. Findings indicate that the number and relevance of messages received affect information processing speed and accuracy and the type of action taken. High message volume resulted in the loss of appropriate information to superiors and subordinates and reduced awareness of battlefield space based on reported locations. Low message relevance resulted in inappropriate relays, slower message processing, and less accurate perception and comprehension of the battlefield situation. Training issues for managing information with future C^2 systems are identified and an innovative method for training information management skills is demonstrated.

14 SUBJECT TERMS
Human performance
Information management
Command, control, and communication (C^3)
Simulation-based training

15 NUMBER OF PAGES
79

16 PRICE CODE
--

17 SECURITY CLASSIFICATION OF REPORT	18 SECURITY CLASSIFICATION OF THIS PAGE	19 SECURITY CLASSIFICATION OF ABSTRACT	20 LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

Technical Report 1000

Information Management Performance of Future Platoon Leaders: An Initial Investigation

Carl W. Lickteig
U.S. Army Research Institute

Cathy D. Emery
University of Louisville

Field Unit at Fort Knox, Kentucky
Barbara A. Black, Chief

Training Systems Research Division
Jack H. Hiller, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

June 1994

Army Project Number
2Q263007A795

Training Simulation

FOREWORD

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) conducts basic and applied research that focuses on meeting the soldier performance challenges facing the Army of today and tomorrow. As part of ARI's program to train the force, the objective of the Future Battlefield Conditions team at Fort Knox is to enhance soldier preparedness through identification of future battlefield conditions and development of training methods to meet those conditions under the program task titled "Technologies for Advanced Mounted Warfare Training."

As the Army moves toward fielding vehicle-based automated command and control (C^2) systems, small unit commanders face many new challenges in managing battlefield information effectively. Based on a simulated method for delivering information management exercises, this report investigates the information management performance of armor platoon leaders using automated C^2 systems. Results demonstrate that information amount and relevance have significant effects on the information management performance of soldiers equipped with such systems. ARI's efforts to better understand how automated C^2 systems will be used should guide the development of training methods to exploit the potential of these systems. Training programs developed to hone information management skills may better ensure the Army's readiness to win the "information war" anticipated on the future battlefield.

ARI's research on training requirements and methods for future automated C^2 systems is supported by the Memorandum of Agreement (MOA) between ARI-Knox and the Tank Automotive Command (TACOM) on Combat Vehicle Command and Control (CVCC) dated 22 March 1989, and the MOA between ARI-Knox and the U.S. Army Armor Center (USAARMC) and Fort Knox titled "Research in Future Battlefield Conditions," 12 April 1989.

This effort was briefed to the Chief of the Command, Control, Communication, and Computer Branch of the Armor School's Directorate of Combat Developments and provided to the Chief of the Mounted Warfare Test Bed (MWTB) and the Chief of the Mounted Warfare Simulation Training Center (MWSTC) at Fort Knox.

EDGAR M. JOHNSON
Director

INFORMATION MANAGEMENT PERFORMANCE OF FUTURE PLATOON LEADERS: AN INITIAL INVESTIGATION

EXECUTIVE SUMMARY

Requirement:

The Army's current focus on precision warfare and the nonlinear battlefield only underscores its longstanding need for advanced command and control (C^2) capabilities. Recent combat experience clearly indicates that if automated C^2 systems are to achieve their potential, they must allow users to extract and process quickly the battlefield information essential to their assigned missions. However, the advent of automated C^2 systems may result in an information deluge that masks essential elements of combat information, particularly for vehicle-based commanders on the forward edge of the battlefield.

Ongoing efforts to "digitize the battlefield" require a clear understanding of how automated C^2 systems will be used and innovative methods of training and assessing the management of information. Based on a simulated method for delivering information management exercises, this report investigated the information management performance of armor platoon leaders using automated C^2 systems.

Procedure:

Participant platoon leaders completed a series of information management exercises that systematically varied the number and relevance of messages received during a simulated delay-in-sector mission. Performance measures included information processing accuracy and speed and the type of actions taken on messages received during each exercise. Additional measures included an objective measure of participants' awareness of the battlefield situations portrayed by the exercises and subjective measures of workload, situational awareness, and the relative contributions of voice versus digital communications for selected command, control, and communication functions.

Findings:

The evaluation demonstrated that information amount and relevance had significant effects on the information management

performance of future platoon leaders equipped with automated C^2 systems. When participants received less information, they relayed more messages, deleted fewer, and plotted reported locations more accurately. When participants received less relevant information, they relayed messages more slowly, relayed fewer messages, deleted and took no action on more messages, and were less accurate in their ability to "see" the battlefield.

Relevance, as defined by message locations inside versus outside the parent unit's assigned sector, proved effective for reducing information management requirements. Acting as information filters, the participants relayed fewer low relevance messages to their superiors and subordinates. Similarly, their relay ratings indicated the need to filter out low relevance messages for their own duty position. The results indicate that the relevance of battlefield information is a key factor in reducing information amount.

The requirement for automated C^2 systems was evidenced by the participants' ratings on the assistance such systems provided. Participants preferred automated C^2 systems over conventional voice communication systems for a variety of command, control, and communication functions rated as very important. Conversely, their ratings indicated that voice-based systems are superior for providing message urgency and feedback on message reception. The need for complementary digital and voice communication systems was clearly indicated.

With respect to the method for delivering information management exercises, automated recordings of message distribution indicated the exercises manipulated information amount and relevance as intended. Participants' relay ratings on the messages received confirmed the exercises differentially conveyed information relevant to their duty position and to their superiors and subordinates. The method's use of surrogate communicators to simulate transmissions from the entire battalion task force resulted in substantial savings in personnel, resources, and equipment. Potential modifications to this method for enhancing its validity and generalizability were identified.

Utilization of Findings:

The findings provide an initial indication of how the information management performance of future platoon leaders may be affected by automated C^2 systems. A better understanding of how information amount and relevance affect the management of information should guide the development of training methods and programs to improve the performance of vehicle-based users of future automated C^2 systems. The method for delivering information management exercises using simulated communications can be

tailored to meet the sometimes conflicting requirements for soldier, leader, staff, and unit readiness in active and reserve component forces. Such readiness may be required to win the "information war" on the future battlefield.

INFORMATION MANAGEMENT PERFORMANCE OF FUTURE PLATOON LEADERS: AN INITIAL INVESTIGATION

CONTENTS

CONTENTS (Continued)

LIST OF TABLES

CONTENTS (Continued)

LIST OF FIGURES

Information Management Performance of Future Platoon Leaders: An Initial Investigation

Introduction

"The command and control process must discriminate, from the flood of information available, those elements essential to the commander to enable him to make timely decisions" (Department of the Army, 1985, Field Circular 71-6, p. 2-2). The advent of automated command and control (C^2) systems, however, may result in an information deluge that masks essential elements of combat information. Particularly for vehicle-based commanders on the forward edge of the battlefield, the revolutionary capabilities of automated C^2 systems to digitize communications may intensify the requirement to manage battlefield information.

The intent of the present research was to assess the information management performance of future platoon leaders equipped with future C^2 systems. This effort focused on the platoon leader's ability to acquire and communicate battlefield information using a vehicle-based C^2 system. In support of this effort, prototype methods for the simulated delivery of platoon leader information management exercises were developed.

Research Requirement

The Army's current focus on precision warfare, the nonlinear battlefield, multinational contingency operations and reduced forces only underscores its long-standing requirement for advanced C^2 capabilities (Foss, 1991). Recent combat experience clearly indicates that if automated C^2 systems are to achieve their potential, they must allow users to extract and process quickly the battlefield information essential to their assigned missions (Burkett, 1991; Foley, 1991; Giboney, 1991).

Armor leads the development of automated C^2 systems for ground combat vehicles. Armor's operational concept of an automated C^2 system for the Abrams main battle tank identifies its potential for improving command and control performance while acknowledging its profound impact on command and control procedures (U.S. Armor Center, 1992). This operational concept describes how tactical commanders at each battalion echelon might use such systems in the conduct of combat operations.

To support Armor's requirement for automated C^2 systems, the Army Research Institute (ARI) at Fort Knox participates in a research and development program on future Combat Vehicle Command and Control (CVCC) systems under the sponsorship of the Tank Automotive Command (TACOM). As the Simulation and Soldier-Machine-Interface team for this CVCC program, ARI conducts simulation-based research on future C^2 system configurations and their training requirements using the Mounted Warfare Test Bed

MWTB) at Fort Knox, formerly SIMulation NETworking Developmental (SIMNET-D).

The MWTB's distributed simulation technology (Chung, Dickens, O'Toole, & Chiang, 1987; Pope, 1987) provides a powerful test bed for soldier-in-the-loop assessment of developmental systems, and particularly systems related to command and control performance (Alluisi, 1991). Simulators in the MWTB serve as reconfigurable weapon systems that emulate the features, capabilities and soldier-machine interfaces anticipated for developmental systems. This evaluation used M1 tank simulators in the MWTB configured with automated C^2 systems under the CVCC program.

Research conducted in the MWTB has primarily targeted the effect of automated C^2 systems on unit-level performance during simulated combat operations. ARI-Knox's supporting efforts in the MWTB include automated C^2 evaluations at the platoon, company and battalion level (Du Bois & Smith, 1991; Leibrecht et al., 1992; O'Brien et al., 1992). Currently, the Mounted Warfighting Battlespace Lab is extending ARI's tank-based program to other branches such as infantry, artillery, and air defense in an effort to integrate horizontally all combined arms through "digitization" of the battlefield. These unit-level, operationally-based assessments have raised the need for complementary efforts to investigate selected C^2 research issues, such as information management, in a more limited but systematic manner.

Despite the shortcomings associated with conventional C^2 systems, a transition to more automated C^2 systems involves many trade-offs (Burkett, 1991; Giboney, 1991) including the potential for increased workload and decreased information. In a workload assessment of the CVCC system, for example, commanders expressed concern that voice-less reporting might increase their workload on tasks such as preparing Contact, Call For Fire, and Spot reports (Morey, Wigginton & O'Brien, 1992). In contrast to digital reporting systems, auditory recognition with voice-based systems may reinforce cues such as information source that aid in relaying reports correctly (Emery and Lickteig, 1991).

This evaluation investigated the effects an automated C^2 system may have on the information acquisition and communication performance of an armor platoon leader. Widespread concerns suggest such systems may overwhelm the ability of tactical commanders to manage information (Burkett, 1991; Foley, 1991; Giboney, 1991). The evaluation's design, therefore, varied the amount and relevance of information a platoon leader was required to process in a typical combat setting. Primary measures addressed platoon leaders' information management performance based on accuracy, speed and action taken on incoming battlefield reports and their ability to assess the battlefield situation described by these communications.

Description of a Future Command and Control System

A brief description of the prototype C^2 system used in this evaluation may illustrate the information management requirements of future small unit commanders in acquiring and communicating battlefield information. A more complete description of this interface, the Command and Control Display (CCD), and its integration with other CVCC component systems is available in LaVine, Lickteig and Schmidt (1993).

The CCD (see Figure 1) provides a wide range of features to aid commanders such as platoon leaders in the performance of their command and control tasks. The CCD integrates information exchanges among on-board and intervehicular systems. Tank components such as navigation and fire control provide internal linkages with the CCD interface. External communications of CCD reports and overlays to similarly equipped vehicles and stations are sent and received using a Single Channel Ground/Air Radio System (SINCGARS) coupled with a radio interface unit. The CCD information management features used in the current evaluation are indicated in Table 1.

A primary objective of the CCD's integrated architecture is to provide each commander an accurate picture of the battlefield situation (LaVine et al., 1993). A sample depiction of the CCD's battlefield situation is provided in Figure 1. This illustration includes a tactical map of the area based on a digital-terrain data base, operational overlay, icons of own, friendly and enemy vehicles, and a preformatted Spot report.

The CCD automatically displays report-based graphic information on its tactical map to maintain an accurate portrayal of the current battlefield situation. For example, an incoming Intelligence report might contain friendly, enemy and obstacle information. As this report is received, the CCD generates icons on the tactical map for each of these report elements. The icons are color-coded, standard military symbols automatically positioned at their reported locations. Similarly, own and friendly vehicle icons are routinely repositioned on the tactical map as the CCD receives location updates from friendly vehicles on the move.

To alert the user to the reception of new information, the CCD generates aural signals (beeps) in the user's headset and visual signals to include flashing report icons and a highlighted RECEIVE key. User activation of the RECEIVE key accesses the Receive Queue, a list of the most recently received messages. Each message "header" in this queue provides information on message source and type as well as reception time. When multiple message headers appear, the commander may decide how and in what order to process reports by reviewing headers in conjunction with report-icon type and proximity information displayed on the tactical map.

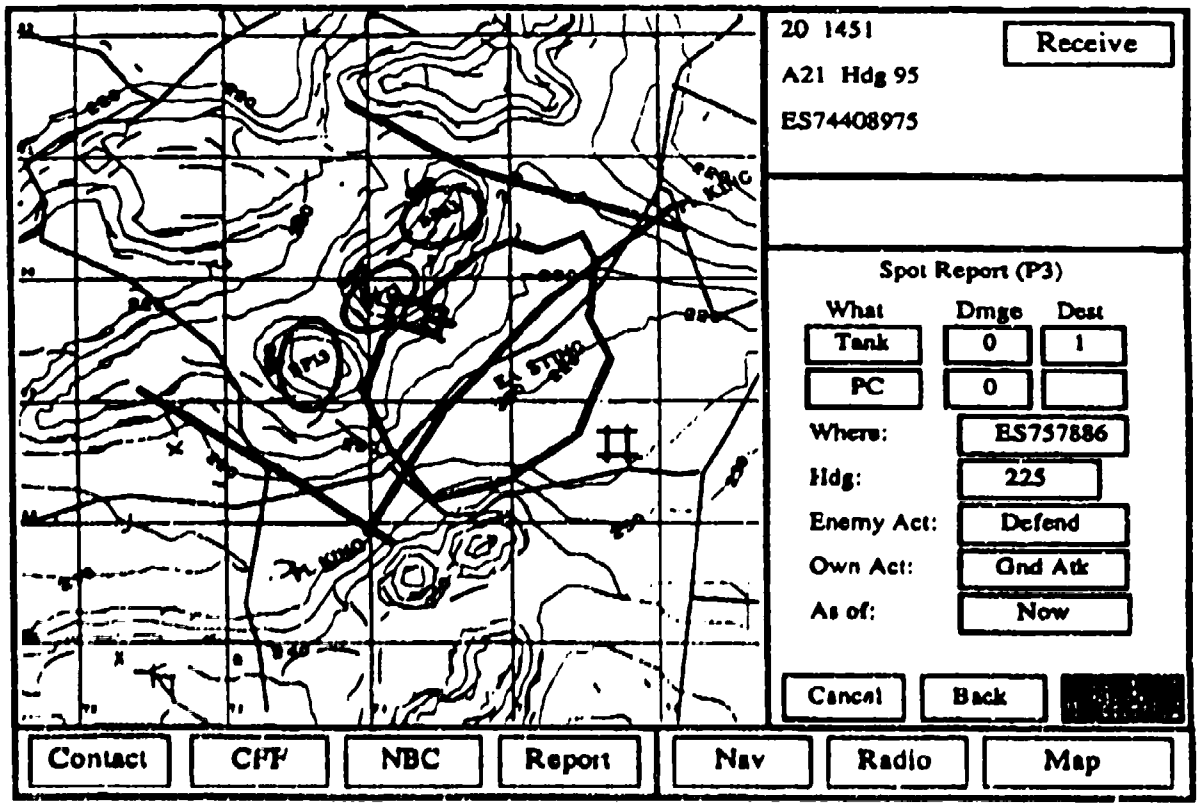


Figure 1. Command and Control Display with digital terrain, overlay, Spot report, and SEND function selected.

The user's selection of a message header highlights its corresponding report icon on the tactical map and identifies the message to be processed. After reading a message, the commander can delete, store or relay the message on the combat radio nets allotted to his respective duty position. Platoon leader relays on the company net are broadcast to his company commander and executive officer as well as the company's other two platoon leaders. Similarly, relays on the platoon net are transmitted to the three tank commanders in his platoon.

As evidenced in this brief description, the information management requirements for automated C² systems are quite different from the procedures currently used with conventional command and control systems based on voice-radio, grease pencils and acetate overlays (U.S. Armor Center, 1992). CCD information management skills for acquiring and communicating battlefield information include knowledge of the procedures to retrieve and relay CCD-based information (Atwood et al., 1991). Proper management of the CCD's information processing capabilities, however, may provide the commander a unique capability to communicate required information to his superiors and subordinates and at the same time visualize the emerging battlefield situation.

Table 1

Features of the Command and Control Display

Digital-terrain map*
Map scale, scroll, and feature manipulation*
Own-vehicle location and heading (analog & digital format)*
Friendly locations at vehicle or unit level*
Route designation
Route transmission
Driver's display showing direction to steer the tank
Far-target designation into digital report formats
Report icons and icon-based report retrieval*
Digital report preparation
Digital report transmission and reception*
Digital overlay transmission and reception

* Features used in this evaluation.

Assessment Issues

A primary concern in the assessment of soldier performance, including information management, is the balance between standardized conditions and operational realism. Standardization problems in training and assessing even small unit tactical performance are well documented (R. A. Baker, Cook, Warnick and Robinson, 1964; Barron et al., 1976; Drucker and Morrison, 1987; R. E. O'Brien, 1986; Schwartz and Floyd, 1963). A vehicle-based commander's information management performance, for example, depends on many ad hoc factors in a force-on-force operation including the direction, speed and formation of own and opposing units. Battlefield simulation, however, can readily support the generation and standardization of tactical task conditions (Goldstein, 1991).

Early efforts in the assessment of tactical information processing devised strategies to standardize information processing requirements. Such strategies included the development of more direct measures of information processing and the use of "probe" messages (Olmstead, Christensen and Lackey, 1973), models for quantifying soldier performance in information systems (J. D. Baker, 1970), and simulation models of soldier-machine interaction (Siegel, Wolf, Leahy, and Bearde, 1977).

Most efforts to assess information management in a military context have addressed staff or command post performance rather than vehicle-based tactical commanders (Crumley, 1989). One pertinent finding was that a staff's ability to communicate information is the primary determinant of their organizational effectiveness (Olmstead, Christensen and Lackey, 1973). However, shortcomings in command and staff information processing demonstrate that personnel are frequently unable to acquire and

communicate needed information (Kaplan, 1987). A prevailing concern is the relevance of the information staff and commanders are required to manage (e.g., Kaplan, 1980; Shoffner, 1993).

While there are fundamental differences in staff versus vehicle-based C^2 procedures, the same C^2 functions are executed by every Army leader using the system available. The C^2 process requires acquiring information, assessing its impact, determining a course of action and directing its execution. "The information is sent and received, the means of communicating the information managed, and the information maintained in a form convenient to the decision-making process" (Department of the Army, 1990, p. 24). Many of the assessment issues related to these functions are identical regardless of setting or unit level.

For small unit information management, more realistic assessments from the National Training Center (NTC) indicate serious shortcomings using conventional C^2 systems that are voice-based. Data from NTC company-level missions revealed that net overload results in almost 30-second waits to access a net, that call signs and authentication procedures account for over one-half of the "information" transmitted, and nearly one-third of all messages are lost due to interference (Phelps and Kupets, 1984). Such information management problems may account for Word's (1987) observation that one of the greatest small unit deficiencies at the NTC is the inability of the platoon leader to assess the battlefield situation.

The commander's ability to "see" the battlefield is regarded as one the most fundamental skills underlying his planning, preparation and execution of the battle. This ability is commonly referred to as situational awareness, a difficult construct to define or measure (Sarter and Woods, 1991) despite recent efforts (Endsley, 1988; Fracker, 1988). Endsley defines situational awareness as: "...the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988, p. 97). A parallel construct is the tactical C^2 Battlefield Operating System function titled Assess the Situation (Department of the Army, 1990).

Situational assessment and awareness measures require consideration of the current and future battlefield situation. In addition, an objective measure of the commander's awareness or assessment of the situation requires accurate knowledge of the actual battlefield situation (Endsley, 1988; Fracker, 1988; Sarter and Woods, 1991).

Finally, a major obstacle in the assessment of voice-based communications with conventional systems is the need to record and transcribe battlefield communications. Voice data capture is a time-consuming, inaccurate and resource intensive process

(e.g., Phelps and Kupets, 1984). For field-based assessments, data collection and reduction systems for voice and digital communications are under development (Palmer, 1992). For simulation-based assessments such as those conducted by ARI in the MWTB, the Data Collection and Analysis (DCA) system captures all battlefield communications transmitted over the Ethernet during simulated combat operations. The digital report formats used by automated C^2 systems such as the CCD enable accurate capture of communications and much of the information management performance of vehicle-based commanders (Leibrecht et al., 1992).

Assessment Methods

The potential of computer-based C^2 systems and soldier-in-the-loop combat simulations support the development of new methods for assessing command and control performance (Du Bois & Smith, 1990). The assessment methods developed for this evaluation with the aid of armor Subject Matter Experts (SMEs) are briefly described in this and the Procedure section. These methods include a set of information management exercises and situational assessment measures targeted at future platoon leader information management requirements.

Information Management Exercises. Development of the information management exercises for this evaluation began with a review of the functions and tasks for "acquire and communicate information" as specified in the tactical C^2 Battlefield Operating System (Department of the Army, 1990). Platoon leader tasks were reviewed (Department of Army, 1988) including a mission-based analysis of the information to be acquired and communicated by this duty position (Drucker and O'Brien, 1982).

In an effort to standardize conditions, the exercises used a vignette structure to generate an operational "snapshot" that realistically includes a flurry of battlefield communications and provides discrete start and stop points. Based on a delay-in-sector mission, each exercise began with the postulated completion of a successful delay by the platoon leader's company and terminated prior to his order to displace to a subsequent battle position (BP). The duration of each exercise was set at 10 minutes. In this operational setting, the platoon leader serves as a vital link in the information chain between lower and higher units and as a unit leader assessing the impact of incoming information on his imminent order to displace.

For each exercise, a prespecified message set comprised the primary information to be acquired and communicated by the platoon leader. In general, each set of messages described the enemy's delay by the platoon leader's task force and provided information pertinent to the platoon's upcoming displacement to a subsequent battle position. Message sets included Contact, Spot, and Intelligence reports in formats available on the CCD that provided the informational elements identified in Table 2.

Table 2

Message Elements Used in Information Management Exercises

Type	From	What	Number/Status			Where	Activity			As Of
			Obs	Dam	Des		Dir	En	Fr	
Contact	x	x	x			x				
Spot	x	x		x	x	x	x	x	x	x
Intel	x	x	x			x	x	x	x	x

Note. X = element available in CCD report format; Obs = observed; Dam = damaged; Des = destroyed; Dir = direction; En = enemy; Fr = friendly; As Of = minutes postdated.

Message content included information from lower, higher and adjacent units. This information had potential importance to the platoon leader, his subordinates and his superiors.

To assess information acquisition and communication performance over differing situations and conditions, the exercises varied battlefield location, threat type and course of action, and information amount and relevance. The postulated enemy unit for each exercise was a motorized rifle or tank regiment in deliberate attack against the platoon leader's task force. For message sets with different levels of information amount and relevance, the enemy units directly approaching the platoon leader's battle position varied in size and course of action.

After development of the message sets, they were loaded on a software utility in the MWTB called SEND that is designed to transmit CCD-based message formats to the CVCC simulators. SEND modifications supported the simultaneous assessment of multiple platoon leaders, counterbalancing the order of message set transmission, and the "isolation" of each platoon leader from coparticipant transmissions. A SEND routine generated fixed-interval pauses between messages to ensure transmission of all messages during the first nine minutes of the exercise.

By simulating message transmissions from the other members of the battalion task force, potentially 57 other vehicle and unit commanders plus staff, conduct of the information management exercises required only platoon leader personnel. As developed, the exercises enable an accurate trace of combat communications across radio nets and echelons as well as the information management performance of participants. This assessment of information flow is regarded as one of more successful methods

employed in C^2 assessment (Solick and Lussier, 1988). In summary, the simulation-based nature of the information management exercises standardized the rapid generation and variation of battlefield conditions and communications.

Situational Awareness. Based on the model proposed by Endsley (1988), the situational awareness measures developed for this evaluation addressed the platoon leader's current and future battlefield situation for each of the information management exercises developed. As the primary determinant of the battlefield situation, the message sets for each exercise provided a firm basis for scoring participants' responses on the situational awareness measures.

A major concern in the assessment of situational awareness (Sarter and Woods, 1991) is to avoid disruption of the situation by "freezing" the operational setting in order to collect situational awareness data. On the other hand, Sarter and Woods warn that after-the-fact data collection may reduce contextual information that might trigger unconscious aspects of awareness. Finally, they caution that post hoc assessments may actually distort one's awareness, particularly in the case of extended operations.

In an effort to avoid distortion in platoon leader awareness, the information management exercise method provided capsulized rather than extended operational situations. In addition, the situational awareness measures for this evaluation were administered immediately after completion of the information management exercises to avoid intrusion into the battlefield situation and the loss of contextual information. The development of these measures attempted to emulate the task context to aid information retrieval (Lord and Maher, 1991). For example, color maps of the digitized battlefield area similar to the CCD's tactical map were provided along with black-and-white xeroxed copies the participants used to plot the requested locations.

Evaluation Objectives and Hypotheses

The primary objective of the evaluation was to obtain preliminary data on the ability of platoon leaders to manage battlefield information using a future automated C^2 system. A secondary objective was to ensure that the method developed for delivering information management exercises operated as expected.

Although automated C^2 systems are regarded as a key component in winning the "information war" on the future battlefield, their potential for information overload is a growing concern. Simulation-based assessments of these systems have demonstrated significant improvement in command and control performance for units equipped with automated C^2 systems. However, no systematic assessment of information load and relevance on the information

management performance of vehicle-based commanders with automated C^2 systems has been conducted.

Information Management Performance

Hypotheses on the information management performance of participant platoon leaders were categorized by accuracy, speed and actions taken on messages processed as well as participants' awareness of the battlefield situation conveyed by each message set. Hypotheses were based on the logical assumptions that higher numbers of messages would overwhelm participants' ability to effectively and efficiently manage the information received and that more relevant information would motivate more effective and efficient information management.

It was hypothesized that participants receiving fewer messages would be more accurate and faster in their overall ability to process messages received. It was also predicted that low amount participants would relay and take action on more messages, delete fewer messages and demonstrate a better awareness of their battlefield situation. With respect to information relevance, it was predicted that low relevance message sets would be processed less accurately and more slowly. It was also predicted that when participants received low relevance message sets, they would relay fewer messages, delete and take no action on more messages and demonstrate less awareness of their battlefield situation.

For ancillary measures involving subjective data, it was predicted that participants receiving fewer messages would rate their workload lower and situational awareness higher. It was also predicted that more relevant message sets would result in higher situational awareness ratings. Participant ratings of the assistance provided by the CCD versus voice-based command and control systems were expected to underscore the complementary nature of these systems for assisting commanders in performing important information management requirements.

Information Management Exercises

The method used to deliver the information management exercises for this evaluation employed simulated CCD-based communications and relied primarily on a communications utility called SEND available in the Maneuver Warfare Test Bed. Method checks are reported for two reasons. First, to ensure this method resulted in standardized manipulations of information amount and relevance as required for this evaluation. Second, to provide information on the applicability of this method for subsequent training and assessment efforts related to information management performance with automated C^2 systems.

To verify the method's manipulation of information amount, a series of checks were expected to demonstrate that participants

received all messages designated for their assigned radio net and amount condition, and that no additional messages were received. Additional messages might result from net "bleedover" during simultaneous transmissions to coparticipants or failure of the "isolate" mode to prevent reception of messages relayed by coparticipants. This assessment also included checks on differential transmission rates for low versus high amount conditions.

To assess the manipulation of information relevance, it was expected that experimenter checks of message locations plotted on the CCD's tactical map would concur with designated in-sector versus out-of-sector company boundaries. In addition, it was predicted that participants' ratings on the need to relay the test messages would be significantly higher on the high relevance message sets.

Method

Participants

Participants for this evaluation were 16 platoon leaders who were active duty armor officers stationed at Fort Knox. On the average, these participants were 27 years old with 4 years of Army service and 1.2 years in armor. Overall, this sample was comprised of 2nd Lieutenants recently graduated from the Armor Officer Basic Course (AOBC) with an average of 2.5 months platoon leader experience. Unless otherwise indicated, all findings reported are based on this sample of platoon leader participants.

Raters for this evaluation were 12 company commanders who were active duty armor officers stationed at Fort Knox. On the average, these raters averaged over 4 years in armor and 17.1 months prior service as platoon leaders. These raters served as subject matter experts (SMEs) for determining platoon leader information requirements. They provided comparison data to assess how well the relatively inexperienced sample of platoon leader participants understood the information requirements for their duty position. Anonymity was ensured for all participants and raters.

Apparatus

The evaluation was conducted in the MWTB and relied on the simulation technologies available in this test bed including the CVCC simulators. In each of four CVCC simulators, the CCDs were mounted right of the vision blocks in the platoon leader's weapon station. The CCD provided all message reception and processing features required for managing the information received during each exercise. The CCD interface was projected on a 13-inch (33 cm), color, cathode ray tube monitor with high resolution (1,250 x 1,024 pixels) and a touch-sensitive screen. The display itself occupied a rectangular region (7 x 5.75 inch, 17.8 x 14.6 cm) in the lower right corner of the monitor.

Each tank simulator's host processor generated battlefield imagery to include own and other participant vehicles colocated on the current battle position for each exercise. The SINCGARS radio in each simulator received and transmitted the reports for each exercise over an Ethernet that linked all simulators with the exercise control room and the Data Collection and Analysis system.

Supporting MWTB utilities in the exercise control room were control consoles for initializing the simulators at the designated battlefield locations for each exercise, a plan-view display for monitoring the exercise, and a SINCGARS and SEND station. The controller's SINCGARS provided a voice-digital link to each simulator to prompt exercise initiation and completion. The SEND terminal transmitted the operational overlays and the required message sets for each exercise. Additional MWTB assets included a classroom for initial orientation and training, and an "extended" classroom in the simulation bay where a CCD demonstration was provided via a large screen, 57-inch (144 cm) diagonal, repeater monitor networked to a stand-alone CCD.

Experimental Design

The design was a 2 x 2 (low and high information amount by low and high information relevance) mixed factorial design with repeated measures on the relevance factor. Participants were run in groups of four and each group was randomly assigned to amount conditions using sampling without replacement. After completing each of the four test information management exercises, the participants completed situational awareness questionnaires for their current and future battlefield situation and provided ratings on situational awareness and workload.

Each test message set for the high amount condition included 21 different CCD reports. Messages sets for the low amount condition included only 9 messages, subsets extracted from each of the high amount message sets. Fixed-intervals between messages of 26 seconds for high amount participants and 60 seconds for the low amount participants ensured reception of all messages in the set during the first nine minutes of each exercise. For the high relevance condition, 100% of the messages received described battlefield conditions within the platoon leader's Alpha company sector. For low relevance, 33% of the received messages described Alpha company sector conditions and the remaining messages described conditions in adjacent company sectors. All participants completed two high relevance and two low relevance message sets.

The design counterbalanced information relevance by message set and situational awareness forms across the four test sessions completed by each group. Plotting and seeing questionnaires for each session alternated between the current and future situation to reduce an item-response set for this after-the-exercise assessment. The Controller's Log in Appendix A provides the

counterbalanced schedule by session including simulators and test materials for a sample group of participants. The message sets used for the test information management exercises are provided in Appendix B. Armor SMEs specified item content for all message sets and situational awareness measures.

Measures

Information Acquisition and Communication. The CCD includes an instrumentation package that automatically records the time and type of operator inputs for many of the CCD functions. The MWTB's Data Collection and Analysis system records, maintains and analyzes the data packets related to simulator dynamics and CCD utilization. For this evaluation, additional measures that more precisely defined the platoon leader's information acquisition and communication performance were developed and integrated into standard Data Collection and Analysis system output files. The primary information acquisition and communication measures for this effort were: message content; message source; time message received; time message opened; message action (e.g., relay, delete, no action; time message action taken; direction (net) message relayed.

Information Requirements. Participant platoon leaders and company commanders completed the platoon leader's Information Requirements questionnaire in their simulators at the end of the day. The questionnaire required each participant to assign relay ratings to the 21 messages included in the high amount message sets. The questionnaire provided a synopsis of each message as presented on their CCDs to ensure ratings were assigned to the correct message. For each message, respondents' ratings indicated if the message should be Relayed To and Relayed By a platoon leader on a 4-point scale ranging from "Definitely Not Relay" to "Definitely Relay."

Situational Awareness. The situational awareness measures used in this evaluation (see Appendix C) targeted the platoon leader's awareness of his current and future battlefield situation based on communications received during each information management exercise. The current situation primarily included items related to the front of his current battle position and the future situation addressed reported information related to his subsequent battle position or beyond current range.

Plotting items required participants to designate on a military map the locations of reported enemy units, friendly units and key control measures. Separate five-item sets of plotting questions addressed the platoon leader's current and future situation (see Table 3). Seeing items required platoon leaders to compile isolated report information into aggregate assessments, to estimate the size of designated enemy units including main and attacking units, and to project the reported information's impact on the platoon's current and future

Table 3

Situational Awareness Items

Current Situation	Future Situation
Plotting	
Largest unit engaged	Support unit to rear
Largest unit approaching	Company's subsequent BP
Friendly scout unit	Obstacle(s) to rear
Target reference points	Enemy scouts to rear
Largest unit outside sector	Mortar unit to rear
Seeing	
Number & type enemy damaged	Distance/direction to main unit
Size & type unit engaged	Heading of main enemy unit
Number & type unit approaching	ETA main unit < 2,000 meters
Size & type force approaching	Distance/direction next BP
Overall size & type unit confronting the task force	Impact of obstacle(s) on unit's next BP

Note. ETA = estimated time of arrival; BP = battle position.

situation. Again, five-item sets addressed the current and future situation (see Table 3).

Each participant's awareness of the situation was dependent on the information provided during each information management exercise. A crosswalk between message sets differing in information amount and relevance by situational awareness items determined the correct answers for each information management exercise. Responses were scored for relative accuracy with a maximum of 10 points per item (see Appendix D). Results on the situational awareness measures are reported as percentage of points obtained on plotting and seeing questionnaire formats.

Ancillary Measures. Additional measures included self-ratings of workload and situational awareness. Ratings of situational awareness were based on a 5-point scale anchored from "No Awareness" to "Complete Awareness." For workload assessment, selected subscales adapted from the NASA-Task Load Index (Hart and Staveland, 1988) addressed perceived mental and physical workload for each information management exercise. Workload was measured on a 5-point scale anchored, for example, from "Very Low Mental Demand" to "Very High Mental Demand."

A final measure asked participants to indicate whether voice-based radio or the CCD would provide the "Most Assistance" for a selected set of command, control and communication functions. The functions selected were not intended to be representative of those comprising the command, control and communication domain. Their selection was based on informal assumptions about some of the key benefits ascribed to each modality. In addition, this questionnaire required participants to rate the importance of each of these functions on a 5-point scale anchored from "Not Important" to "Extremely Important." Ancillary measure formats are provided in Appendix E.

Procedure

Procedures for the participant platoon leaders are described below. Procedures for the raters, SME company commanders, were essentially the same. The primary difference was that company commanders' training and evaluation sessions were tailored to their duty position, Alpha company commander (A06). When providing relay rating data, however, the company commanders worked as surrogate platoon leaders and received the same messages and message sets used for the participant platoon leaders. For this report, only the rating data obtained from these company commanders on the platoon leader's Information Requirements questionnaire was used.

Training and data collection sessions for the evaluation were conducted in groups of four and required one day per group. During the AM period, participants received an overview brief on the evaluation, a group-level demonstration of the CCD, and two practice sessions conducted in their simulators. Training and evaluation sessions employed the same structure beginning with an information management exercise in which each participant received, processed and relayed the designated message set followed by completion of the situational awareness and workload measures. Each session required approximately 30 minutes. The PM period commenced with a final practice session followed by four test sessions. After a classroom debrief and questionnaire session, participants returned to their simulators and provided relay ratings on two of the four high amount message sets used in the evaluation. The training and testing schedule is provided in Appendix F.

Instructions to the participants in the overview brief and during training sessions addressed information management issues with the CCD. Instructions stressed that participants should base their relay decisions on the trade-offs associated with information overload and the receiver's need-to-know. Training session and classroom instructions described the CCD's default routing mechanism for relaying messages. The default parameters were that Intelligence reports automatically selected the downward net (i.e., platoon net) and Spot and Contact reports, the upward net (i.e., company net). Training stressed manual override of the default net selection when required and cautioned

that over-reliance on the default mechanism might result in relays on the wrong net.

The operational setting for all exercises designated each participant as the platoon leader of the second platoon of Alpha company (A21). Alpha company always occupied a central sector within the task force and its second platoon was assigned the central battle position, current and subsequent, within the company's sector. As part of their assigned role, participants were expected to maintain their awareness of the battlefield situation based on incoming reports and be prepared to direct their unit to a subsequent battle position as the situation required. At the same time, they were to maintain the awareness of their superiors and subordinates by forwarding, or relaying, as many of the reports as warranted.

Five minutes prior to the start of each session, participants were provided a 1:50,000 scale military map sheet, map board, and acetate operational and note overlays for their current location and operational situation. An extract of an operations order, see Appendix G, was also provided to aid participants in their transition through the series of practice and test exercises varying battlefield locations and situations. At the start of each session, all CCDs were configured at 1:50,000 scale and centered at the location of each platoon leader's unit.

When all participants in the group responded "REDCON 1" to the controller indicating ready, the information management exercise began with the controller's activation of a SEND-executable file that initiated message set transmission. During the exercise, participants received the designated messages on their CCD and were expected to process each message as appropriate to their duty position including relays to superiors and subordinates. They were allowed to make any notes on their acetate note overlay concerning the information received.

Immediately after completion of the information management exercise portion of the session, participants were escorted out of the simulators to separate work areas for completion of the situational awareness and workload measures. Upon leaving the simulator, each platoon leader returned to the support personnel the map board, overlays and any notes he might have made during the exercise concerning the information received. Participants recorded responses for the seeing measure on their questionnaire and plotted locations on a black-and-white xerox copy of the colored map sheet for the plotting measure. Upon completion of the questionnaires, each participant "backbriefed" to support personnel his situational awareness and workload responses to verify all answers were interpreted correctly.

After completion of the final information management exercise and situational awareness questionnaires, each group of participants returned to the classroom for a final debrief. During this session each participant completed the ancillary

measure on the relative importance of selected command, control and communication functions and their assessment of whether the voice-based radio or CCD the would provide the most assistance in performing each function.

Participants were then instructed on completion of a final questionnaire intended to determine platoon leader information requirements. After this questionnaire's format and response alternatives were reviewed, participants returned to their simulators where they received two of the high amount message sets on their CCDs. For each message, participants rated whether it should or should not be relayed "to" and "by" a typical platoon leader in this situation. During this rating session, no time constraints were imposed and participants were not required to relay the messages or prepare for a subsequent situational awareness assessment.

Analysis. All analyses were performed using SPSS/PC+ routines (Norusis, 1988). Primary analyses used the multivariate analysis of variance (MANOVA) program for repeated measures. All interactions were tested using MANOVA simple effects tests that maintained the overall mixed-model and used separate error terms at each level of the variable tested. Additional analysis procedures are indicated as results are reported.

For comparability, analyses on message processing accuracy, speed and type of action taken were based on the 36 identical messages (9 messages per set x 4 test exercises) commonly received by participants in the low and high amount conditions. Common messages within each set were received in the same order by all participants with additional messages interspersed for the high amount condition (Appendix B). Results on the additional messages received by the high amount condition are not reported but were similar to those for the common set.

Unless otherwise indicated, repeated measures within a level of relevance were collapsed. The primary distinctions between equivalent relevance sets were battlefield location and threat type. Differences on these factors were neither expected nor detected. The locations were successive battle positions within a company-level defensive scenario (Leibrecht et al., 1992) and provided very similar terrain and boundary features. Tank versus mechanized rifle regiment threat types were based on Soviet force structures and comprised a mix of tank and personnel vehicles rather than "pure" threat types.

Results

This section begins by considering evidence obtained that assignment of participants to the high and low amount conditions resulted in equivalent groups and that the platoon leader participants correctly understood the information management requirements for their duty position. Substantive findings related to the effects of message number and relevance on

participants' information management performance are then reported, followed by findings based on ancillary measures. Finally, data obtained to check the method used for delivering and standardizing information management exercises used in this evaluation are presented.

Group Equivalence

Results indicated that the low and high amount conditions were equivalent with respect to age, military service, time in armor and the platoon leader duty position, and prior computer experience. Results from a series of analysis of variance (ANOVA) tests on these biographical items with amount as the between-subjects factor are presented in Table 4. Random assignment appeared to successfully equate the low and high amount groups. Subsequent differences on dependent measures should not be the result of prior differences on any of these measures.

Understanding of Platoon Leader Information Requirements

In preface, the results indicated the sample of platoon leaders correctly understood the information requirements for their duty position. This was a key concern due to the limited experience of the primary participants as platoon leaders. Recall, the Information Requirements questionnaire was developed to assess the participants' knowledge of what information a platoon leader needed to acquire (Relay To) and communicate (Relay By) based on all messages developed for the information management exercises.

The mean relay ratings by platoon leaders and SME company commanders are provided in Table 5. These ratings include the Relay To and Relay By categories and are based on all messages developed for the four high amount message sets. Measures of interrater agreement provided in Table 6 indicate that the platoon leader ratings concurred with those provided by the company commanders. The Cronbach estimates were based on the Alpha Model (Norusis, 1988) using platoon leader versus company commander mean ratings for each message. The Alpha values ranged from .44 to .94 suggesting substantial agreement between platoon leaders and company commanders.

These estimates were limited by positively skewed rating distributions for the low relevance message sets and negatively skewed distributions for the high relevance sets. Whitehurst (1984) urged the use of Finn's index to overcome limitations associated with traditional measures of interrater agreement affected by response distributions. Finn's index is based on observed within-subjects variance adjusted by expected within-subjects variance for ratings randomly assigned and is less affected by rating distributions (Whitehurst, 1984).

Table 4

Source Table on Group Equivalence by Information Amount

Source	df	Mean Square	F	p
Age Amount	1,14	4.0	.29	.60
Service Experience Amount	1,14	0.3	.00	.99
Armor Experience Amount	1,14	306.3	.75	.40
Platoon Leader Experience Amount	1,14	42.3	1.22	.29
Computer Experience Amount	1,14	0.1	.11	.74

The Table 6 values obtained for Finn's index ranged from .89 to .97 demonstrating substantial interrater agreement between the ratings provided by the platoon leader sample and the more experienced company commanders. Finally, computed probabilities for Kendall's coefficient of concordance indicated significant agreement between platoon leader and company commander ratings for each of the message sets developed (all $ps < .03$).

Message Processing Accuracy

Accuracy data are reported from three sources. First, comparisons between participant platoon leader relay performance and company commander relay ratings are presented. Next, comparisons between participant relay performance and their own relay ratings are presented. Finally, participant selection of combat radio net for message relay is considered.

Based on Company Commander Relay Ratings. In preface, information amount had no overall effect on relay accuracy, contrary to prediction. However, information amount did affect the type of relay errors made. Participants receiving fewer messages relayed significantly more information and participants receiving more messages relayed significantly less. As predicted, messages from the high relevance message sets were relayed more accurately. The primary source of error, with respect to relevance, was the relay of too many messages from low relevance message sets.

Recall, that participants' concurrence with the company commanders' relay ratings indicated they correctly understood

Table 5

Mean Relay Ratings (and SDs) by Platoon Leaders (PLs) and Company Commanders (CCs) on Relay To and Relay By Categories

Ratings	LR_1	LR_2	HR_1	HR_2
Relay To				
PLs	3.20 (.27)	2.96 (.37)	3.59 (.12)	3.79 (.20)
CCs	3.17 (.46)	2.67 (.51)	3.36 (.27)	3.67 (.20)
ReLay By				
PLs	2.82 (.38)	2.51 (.44)	3.32 (.26)	3.46 (.12)
CCs	2.61 (.50)	2.45 (.28)	2.92 (.25)	3.49 (.10)

Note. LR = Low Relevance, HR = High Relevance. PL's N = 16, n = 8 per message set. CC's N = 12, n = 6 per message set.

Table 6

Interrater Agreement of Platoon Leaders and Company Commanders on Platoon Leader Information Requirements by Message Set

Ratings	Cronbach's Alpha	Finn's Index	Kendall's Concordance W	Kendall's Concordance χ^2	Kendall's Concordance p
Relay To					
Low Relevance$_1$	.84	.92	.48	105.6	.00
Low Relevance$_2$	.85	.86	.51	161.7	.00
High Relevance$_1$	.94	.97	.34	103.4	.00
High Relevance$_2$	.44	.96	.11	34.1	.03
Relay By					
Low Relevance$_1$	.85	.89	.45	135.0	.00
Low Relevance$_2$	.94	.91	.56	178.1	.00
High Relevance$_1$	.90	.93	.37	110.8	.00
High Relevance$_2$	.68	.94	.16	48.4	.00

Note. For platoon leaders, N = 16 and n = 8 per message set. For company commanders, N = 12 and n = 6 per message set.

their information requirements in a nonoperational setting. In contrast, the information management exercises were designed to assess their performance in a simulated operational setting. While limited, conditions for this setting included the simulated "pace of operations" generated by information amount, external time constraints and the requirement to maintain awareness of the emerging battlefield situation.

To assess relay accuracy on each of the nine common messages in each message set, participant's relay performance during the simulated information management exercises was compared with the company commanders' mean Relay By rating for each message. An accurate relay was defined as equivalent relay performance and rating, based on dichotomous categorization of the rating data. For inaccurate relays, over relay was defined as participant's relay of a message that company commanders rated "Definitely Not Relay" or "Not Relay." Under relay was the failure to relay a message company commanders rated "Definitely Relay" or "Relay."

Mean percentages and standard deviations on inaccurate relays by information amount and relevance are provided in Appendix H, based on company commander ratings. Types of error reported are over and under relays. Corresponding percentages are provided in Figure 2. Results from a repeated measures MANOVA on number of inaccurate relays are provided in Table 7.

Overall, participants accurately relayed 77.7% of the common set messages received during the information management exercises, based on company commander ratings. Although information amount had no overall effect on relay accuracy, the Amount x Type of relay error interaction was significant (Table 7). Simple effects test revealed that low amount participants relayed more of the messages that company commanders had rated as not appropriate for relay (F 1,14 = 28.12, p = .000) and high amount participants relayed significantly fewer of the messages rated as appropriate for relay (F 1,14 = 13.85, p = .002).

Overall, participants accurately relayed 67.4% of the messages from low relevance sets and 88.0% of the messages from high relevance sets, based on company commander ratings. As predicted, messages from the high relevance message sets were relayed more accurately (Table 7). A simple effects test revealed significantly more over relays on the low relevance message sets (F 1,14 = 28.01, p = .000).

Based on Own Relay Ratings. Comparisons with platoon leaders' own relay ratings were conducted to provide additional information on relay errors. In preface, results on information amount were similar to those based on company commander ratings but information relevance had no effect. As with company commander ratings, participants receiving fewer messages relayed too much information while participants receiving more messages did not relay enough.

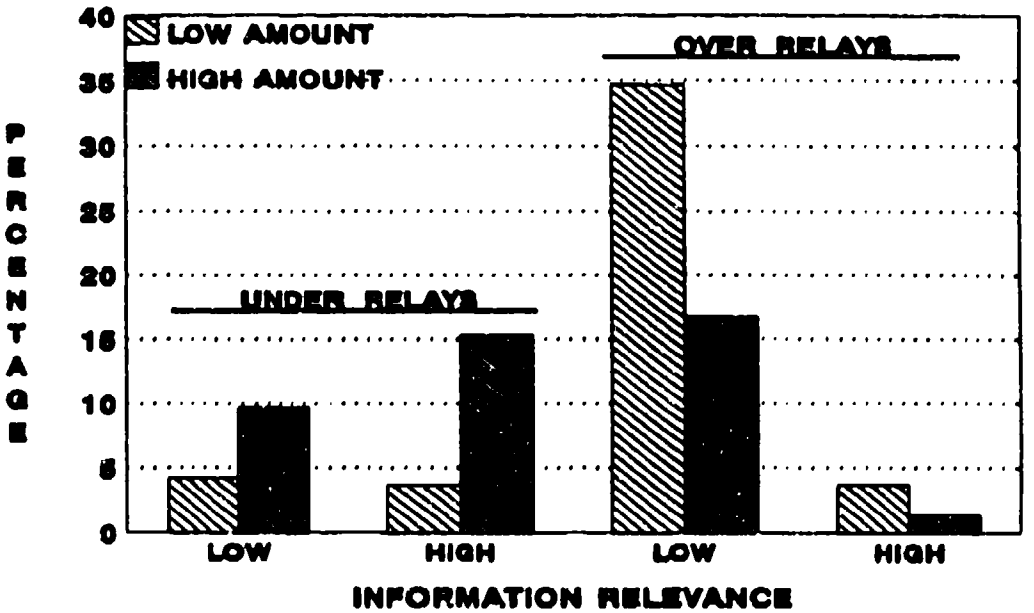


Figure 2. Message processing accuracy: Mean percentage of relay errors based on company commander relay ratings.

The tabulation of relay errors was identical to that used with company commander ratings except that each participant's relay performance was compared with his own relay rating on each message. Mean percentages and standard deviations on inaccurate relays by information amount and relevance are provided in Appendix H, based on platoon leader ratings. Results from a repeated measures MANOVA on number of messages inaccurately relayed are provided in Table 7.

Overall, participants accurately relayed 73.9% of the common set messages received during the information management exercises, based on participant ratings. Although information amount and relay error type were significant, interpretation is dependent on the significant Amount x Type interaction (Table 7). A simple effects test revealed that low amount participants relayed more of the messages that company commanders had rated as not appropriate for relay (F 1,14 = 38.33, p = .000). Similarly, high amount participants relayed significantly fewer of the messages rated as appropriate for relay (F 1,14 = 26.53, p = .000).

Based on Relay Net Selections. A related measure of message processing accuracy was correct net selection for each message relayed. Recall, that if the CCD's default selection was incorrect, participants could simply override the default by selection of the correct net. On messages relayed, participants accepted all correct default net selections and 25% of all incorrect default net selections. There were no significant differences in net selection by information amount and only low relevance message sets included incorrect default selections.

Table 7

Source Table on Inaccuracies in Message Processing by Information Amount, Relevance, and Type of Error (Over and Under Relay)

Source	df	Mean Square	F	p
Platoon Leader Relays Versus Company Commander Relay Ratings				
PL vs CC				
Amount	1,14	0.1	.08	.78
Relevance	1,14	13.8	12.81	.003**
Type	1,14	4.5	2.19	.16
Amount by Relevance	1,14	3.8	3.58	.08
Amount by Type	1,14	11.4	5.53	.03*
Relevance by Type	1,14	21.4	34.85	.000***
Amount by Relevance by Type	1,14	0.8	1.25	.28
Platoon Leader Relays Versus Own Relay Ratings				
PL vs Own				
Amount	1,14	27.6	4.60	.05*
Relevance	1,14	7.6	1.81	.20
Type	1,14	45.6	8.75	.01**
Amount by Relevance	1,14	5.1	1.21	.29
Amount by Type	1,14	52.6	10.10	.007**
Relevance by Type	1,14	0.6	0.13	.72
Amount by Relevance by Type	1,14	0.1	0.01	.90

*p<.05. **p<.01.

Message Processing Speed

In preface, the time to open messages received was not significantly affected by information amount or relevance, contrary to expectations. High amount participants, however, opened messages five seconds slower, on the average. The read time for high amount participants was significantly shorter than that of low amount participants. As predicted, read time for the high relevance message sets was significantly faster. Contrary to expectation, relay time was not significantly affected by information amount. As predicted, messages from high relevance exercises were relayed faster.

The primary message processing speed measures were the time to open, read and relay the messages received during the information management exercises. Means and standard deviations on each of these measures for messages processed while in the CCD

Receive Queue are provided in Appendix H. Corresponding mean times are provided in Figure 3. Results from repeated measures MANOVAs on time to open, read and relay messages in the Receive Queue are provided in Table 8.

Messages not acted on while in the Receive Queue could be processed under a CCD feature called Old Files. Limited activity in the Old Files precluded processing speed comparisons. Results for Old Files are provided in a following section titled Message Processing Actions.

Opening Time. Message opening time was defined as elapsed time from CCD message reception to participant's activation of the SHOW key which displayed that message's textual content. For messages relayed from the Receive Queue, average opening time was 8.2 seconds for the low amount condition and 13.2 seconds for high amount. As indicated in Table 8, these opening times were not significantly different by information amount. Multivariate homogeneity of variance tests on opening times revealed significantly greater variability by high amount participants, Box's $M = 29.2$, χ^2 (3, $N = 16$) = 24.7, $p = .00$. Opening time by message set relevance indicated participants tended to open messages from the high relevance messages sets more quickly but this difference was not significant ($p = .07$).

Read Time. For relayed messages, time to "read" was based on elapsed time from message opening to activation of the PREP key which prepared that message for relay. Read time included the time to comprehend the message, to determine appropriate message action (relay, delete, take no action) and any time participant might have elected to take notes on the message's content. For messages relayed from the Receive Queue, the overall average read time was 24.0 seconds for the low amount condition and 17.3 seconds for high amount participants. As anticipated, read times for the high amount condition and high relevance message sets were significantly faster (Table 8).

Relay Time. Relay time was based on time from message reception by the CCD to activation of the SEND key by the participant. Relay time included opening time, read time and any additional time spent on net selection and message posting to the CCD's map display. For messages relayed from the Receive Queue, average relay time was 32.1 seconds for the low amount condition and 30.4 seconds for high amount. Contrary to expectation, relay times were not significantly different between groups (Table 8) but the relay times for high amount participants were more variable. Bartlett-Box homogeneity tests on relay times for low relevance (F 1,588 = 5.68, $p = .02$) and high relevance (F 1,588 = 4.21, $p = .04$) message sets were significant and the multivariate test approached significance, Box's $M = 8.6$, χ^2 (3, $N = 16$) = 7.3, $p = .06$. As expected, the high relevance message sets had significantly faster relays than low relevance message sets.

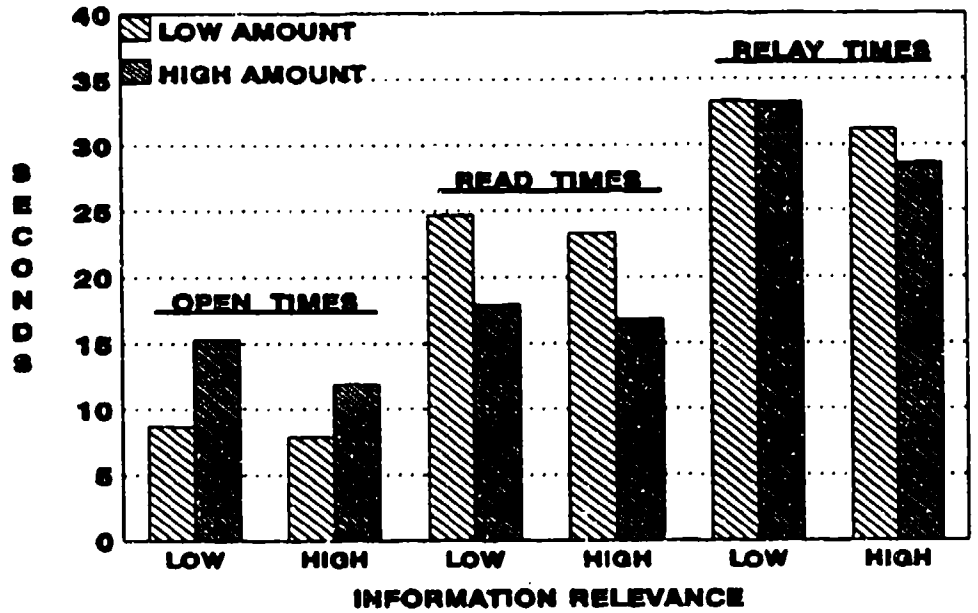


Figure 3. Message processing speed for receive queue relays by information amount and relevance.

Delete Time. For messages deleted from the Receive Queue, opening times and relay times were similar to those for messages relayed. However, the overall average read time for messages deleted was 16.2 seconds compared to 20.7 seconds for messages relayed. As the low amount condition deleted no messages from the high relevance message sets, a repeated measures MANOVA was performed on only the high amount condition. Although not predicted, this analysis indicated that messages in the Receive Queue were deleted significantly faster than they were relayed (F 1,6 = 9.22, p = .02).

Message Processing Actions

In preface, low amount participants relayed more messages and deleted fewer messages, as predicted. Contrary to expectation, no difference was found for number of messages acted on between the two amount conditions. As predicted, messages from the high relevance message sets were more frequently relayed and acted on and less frequently deleted.

Receive Queue Actions. Message processing actions analyzed were message relay, message deletion, no action, and failure to open a message received. Only opened messages could be relayed and a message in the Receive Queue could not be both relayed and deleted. If a message was neither relayed nor deleted, message processing was classified as no action. Messages not opened, no activation of the SHOW key, were classified as such. It should be noted that failure to open a message is not necessarily an incorrect response. A message's icon is automatically depicted on the CCD's tactical map at time of reception, prior to opening.

Table 8

Source Table on Speed of Message Processing by Information Amount and Relevance

Source	df	Mean Square	F	p
Opening Time				
Amount	1,14	224.7	2.40	.14
Relevance	1,14	35.5	3.84	.07
Amount by Relevance	1,14	13.8	1.49	.24
Read Time				
Amount	1,14	353.8	8.32	.01**
Relevance	1,14	12.5	4.63	.05*
Amount by Relevance	1,14	0.1	.04	.85
Relay Time				
Amount	1,14	14.6	.09	.77
Relevance	1,14	90.1	10.40	.01**
Amount by Relevance	1,14	11.5	1.33	.27

*$p<.05$. **$p<.01$.

The information it provides on unit type, alignment (friendly or threat) and proximity may suffice.

Mean percentage data for each of the four types of message actions by information amount and relevance are provided in Appendix H. Corresponding percentages for messages relayed, deleted and not acted on are presented in Figure 4. Due to patterns of nonnormality and heterogeneity, a series of nonparametric analyses were conducted on mean number of message actions for each action type.

Overall, more than three-fourths of all such messages received were relayed and 14.2% were deleted. A small, but substantial, portion (8.3%) were not acted on while in the Receive Queue. A series of Mann-Whitney U tests indicated significant differences, as anticipated, between the low and high amount conditions on number of messages relayed ($U = 8.0$, $p = .01$) and number of messages deleted ($U = 2.0$, $p = .00$) with two-tailed probabilities corrected for ties.

These comparisons indicated the low amount condition relayed more messages and deleted fewer relative to high amount participants. No difference was found for number of messages not acted on between the two amount conditions. Overall, all but three of the common set messages received were opened. Only participants in the low amount condition left messages in the Receive Queue unopened, a nonsignificant difference ($p = .06$).

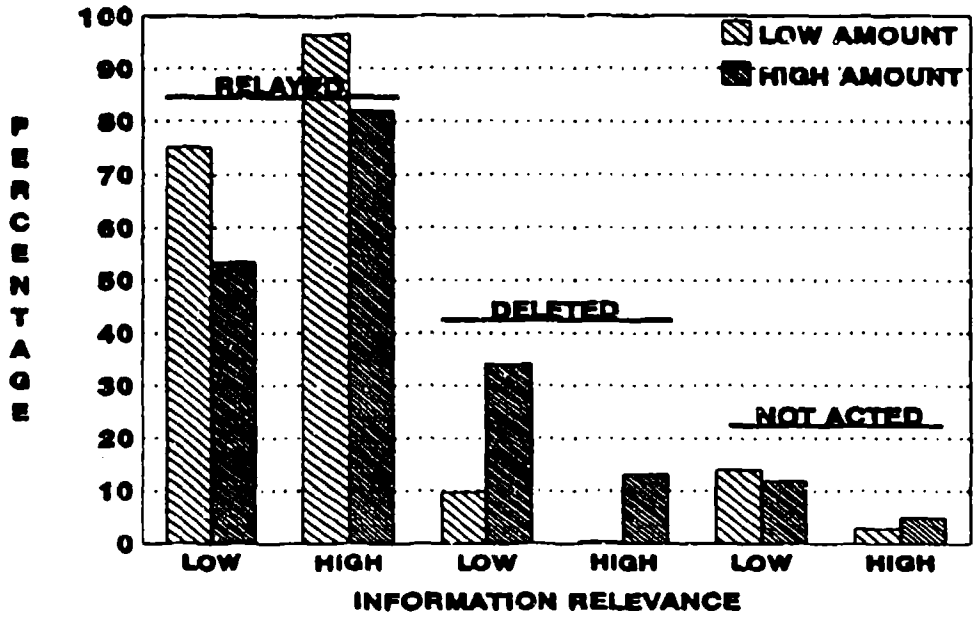


Figure 4. Message processing actions in the receive queue by information amount and relevance.

The effect of information relevance on mean number of message actions taken was assessed with a series of Wilcoxon Matched-pairs Signed-ranks tests on low and high relevance message sets. As expected, relevance differences were found for number of messages relayed (Z = -3.516, two-tailed p = .011), number of messages deleted (Z = -3.139, two-tailed p = .002) and number of messages not acted on (Z = -2.251, two-tailed p = .024). These results confirmed that messages in the high relevance sets were relayed more frequently and deleted less often, and that messages in the low relevance sets were more likely to receive no action.

Old Files Actions. As noted, nearly all message activity occurred while the messages were in the Receive Queue. The CCD's Old Files were designed for more extended operational settings but during the information management exercises the Old Files stored a copy of each message received that was not explicitly deleted by the participants. Presumably, the 10-minute duration of the information management exercises restricted the need or ability of participants to review messages stored in Old Files. Notably, no high amount participant used the Old Files. Five of the eight low amount participants accessed messages stored in Old Files, but only 10 of the Old File messages were relayed or deleted. As 7 of these 10 actions were message deletions, Old File activity primarily appeared to be of a "housekeeping" nature.

Situational Awareness

In preface, low amount participants more accurately plotted locations on the information received during the information

management exercises, as predicted. Contrary to expectation, low amount participants were not better at seeing the battlefield situation reported. As predicted, participants were better at seeing the battlefield situation conveyed by high relevance message sets. Contrary to expectation, plotting performance was not affected by information relevance.

Recall, that separate questionnaires for measuring plotting and seeing performance were developed to assess participants' awareness of the battlefield situation depicted by each message set. Alternate forms of each questionnaire type were designed to measure participants' awareness of the current and future battlefield situation.

Mean percentages and standard deviations obtained on plotting and seeing performance are provided by information amount and relevance in Appendix H. Corresponding percentages are presented in Figure 5. As performance on the plotting and seeing measures was not correlated, a multivariate analyses combining plotting and seeing performance was not conducted. Repeated measures MANOVAs for plotting and seeing percentage data by information amount, relevance and situation were conducted and are summarized in Table 9.

Across all platoon leader participants, the mean percentages for plotting and seeing were 46.2% and 69.5%, respectively. When performance on the plotting and seeing measures were combined, mean percentages on situational awareness were 60.2% for the low amount condition versus 55.4% for the high amount. For the plotting data, overall percentages for the low versus high amount conditions were 52.0% and 40.3%, respectively.

As expected, the low amount condition performed significantly better in plotting the battlefield situation depicted by the information management exercises (Table 9). Contrary to expectation, information relevance had no effect on plotting performance. Overall percentage data for plotting the current battlefield situation was 41.8% compared to 50.5% for the future situation, a difference only approaching significance. None of the two-way interactions for plotting were significant, but the three-way interaction of Amount by Relevance by Situation was significant. A simple effects test indicated that when plotting the future situation, low amount participants were more accurate on low relevance exercises while high amount participants were more accurate on high relevance exercises (F 1,14 = 5.99, p = .03). This interaction was neither anticipated nor understood.

For the seeing data, overall percentages for the low versus high amount conditions were 68.4% and 70.5%, respectively. Contrary to hypothesized expectancies, this difference was not significant. Participants averaged 74.5% on the high relevance message sets compared to 64.4% on the low relevance sets for seeing data. As predicted, participants ability to see the battlefield situation was significantly better on the high

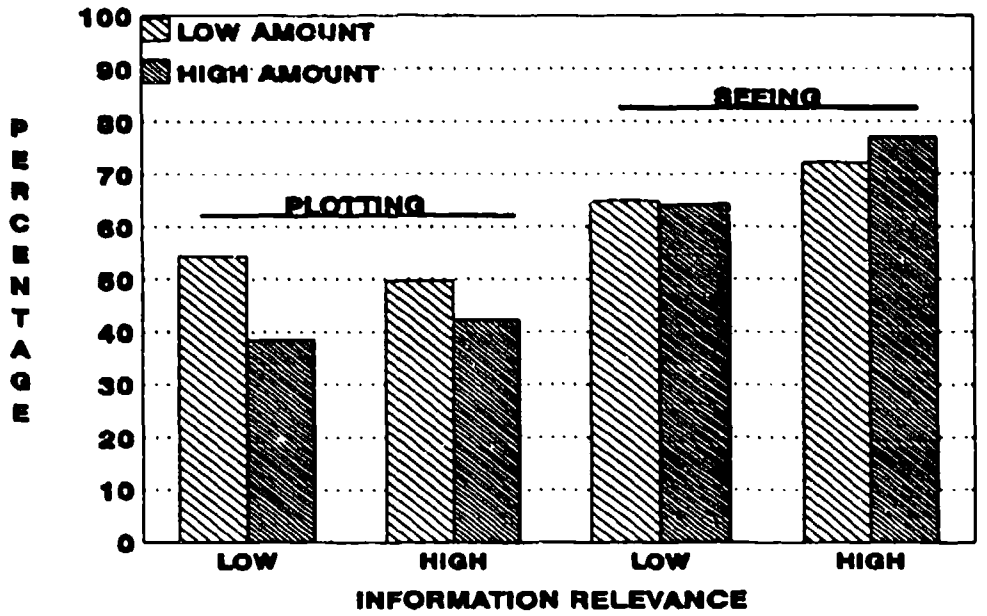


Figure 5. Situational awareness percentages for plotting and seeing by information amount and relevance.

relevance message sets (Table 9). Participants' seeing performance averaged 65.7% on the current battlefield situation compared to 73.3% for the future situation, a nonsignificant difference. None of the interactions on seeing performance were significant.

Ancillary Measures

In preface, significant differences were not obtained on participants' subjective assessment of situational awareness or workload during the evaluation, contrary to prediction. As predicted, ratings on the assistance provided by the CCD versus voice-based radio were highly discriminant and indicated the complementary need for both systems to support command, control and communication functions.

In general, participants rated their awareness of the battlefield situations depicted by the information management exercises near the "High Awareness" anchor with an overall mean rating of 3.81, standard deviation = .57. Mean situational awareness ratings for low versus high amount conditions were in the expected direction, 3.97 and 3.66 respectively. Across all message sets, mean rating for mental workload was 3.09 and for physical workload, 1.61. This difference was significant based on the Wilcoxon Matched-pairs Signed-ranks Test (Z = -3.4078, 2-tailed $p < .001$).

Overall mean ratings on the importance of selected command, control and communication functions are provided in Table 10 by rank order. Mean ratings ranged from 4.88 (5.0 = "Extremely

Table 9

Source Table on Situational Awareness Measures by Information Amount, Relevance, and Situation

Source	df	Mean Square	F	P
Plotting				
Amount	1,14	2209.0	4.74	.047*
Relevance	1,14	4.0	.01	.910
Situation	1,14	1190.3	3.96	.067
Amount by Relevance	1,14	200.6	.93	.351
Amount by Situation	1,14	390.1	1.30	.274
Relevance by Situation	1,14	138.1	.68	.422
Amount by Relevance by Situation	1,14	1156.0	5.72	.031*
Seeing				
Amount	1,14	68.1	.45	.513
Relevance	1,14	1620.1	19.60	.001***
Situation	1,14	915.1	2.27	.154
Amount by Relevance	1,14	115.6	1.40	.257
Amount by Situation	1,14	885.1	2.20	.160
Relevance by Situation	1,14	264.1	1.67	.218
Amount by Relevance by Situation	1,14	517.6	3.26	.092

*p<.05, ***p<.001.

Important") for "keeping your eyes on the battlefield" to 2.94 (3.0 = "Average Importance") for "ensuring standard message formats."

Ratings on voice-based versus CCD mode for assistance in performing selected command, control and communication functions were polarized, as expected. Binomial tests on voice versus CCD assistance were significant for 11 of the 13 functions rated, as indicated in Table 10. The voice-based mode was rated as providing significantly more assistance for "expressing message urgency" and "receiving feedback on messages received." On the other hand, participant ratings on assistance provided by the CCD were significantly higher than voice-based radio for nine of the selected functions assessed.

Method Checks on Information Management Exercises

In preface, the information management exercises developed for this evaluation successfully standardized and manipulated information amount and relevance, as expected. Data obtained on method checks are provided below and modifications for improved validity and generalizability are provided in the Discussion and Conclusions sections.

Table 10

Mean Importance of Selected Command, Control, and Communication Functions and Preferred Mode (Voice or CCD) Based on Assistance Provided

C³ Function	Importance	Assistance
Keeping your eyes on the battlefield	4.88 (.34)	Voice
Maintaining situational awareness	4.56 (.63)	CCD **
Ensuring good "copy" of the message	4.56 (.73)	CCD **
Linking reported locations to the map	4.38 (.72)	CCD ***
Expressing message urgency	4.31 (.95)	Voice **
Issuing FRAGO graphics	4.13 (1.02)	CCD ***
Receiving operational overlays	4.13 (.96)	CCD ***
Maintaining map/overlay alignment	3.94 (.68)	CCD ***
Relaying messages received	3.87 (.50)	CCD
Receiving feedback message received	3.81 (.66)	Voice *
Providing easy access to map data	3.81 (.83)	CCD ***
Saving/recording message contents	3.44 (.81)	CCD ***
Ensuring standard message formats	2.94 (.85)	CCD ***

Note. Mean importance ratings rank ordered with standard deviations in parentheses. Importance scale anchors ranged from 1 = "Not Important" to 5 = "Extremely Important." Voice or CCD mode with higher assistance rating is indicated by function and probability: * < .05, ** < .01, *** < .001. N=16.

Examination of the message locations on the CCD by the authors showed they concurred with designated company sector boundaries. Participants' relay ratings also indicated successful manipulation of information relevance. Overall mean relay ratings for low versus high relevance message sets were computed for pairwise comparison using the Wilcoxon Matched-pairs Signed-ranks test. Relay ratings for high relevance message sets were significantly greater than low relevance sets for both the Relay To (Z = -4.01, two-tailed p < .000) and Relay By (Z = -3.96, two-tailed p < .000) rating categories.

Similarly, across platoon leader and company commander participants, mean relay ratings on Relay To category were significantly higher than Relay By ratings. These comparisons were based on Wilcoxon Matched-pairs Signed-ranks tests with Zs ranging from -2.80 to -2.93 and all two-tailed ps < .0035.

The manipulation of information amount was primarily dependent on the reliability of the SEND program routines developed to systematically vary the number and content of messages in each message set. These SEND routines were also designed to transmit counterbalanced message sets simultaneously to the four participants in each group, to ensure each set was exclusively transmitted on each participant's designated simulator radio net, and to maintain the fixed-interval schedule between the messages in each set.

Review of the data logger transmission files indicated reliable performance of the SEND routines. All but one of the 960 total test transmissions were successful and all 576 (9 x 4 x 16) common set transmissions were successful. The lone transmission failure was not a common set message. No net "bleedover" was detected indicating participants received only the messages assigned to their condition. Fixed-interval schedules were maintained within three seconds, considered acceptable. As intended, the exercises provided approximately one minute after full-set transmission to complete information management requirements and prepare for situational awareness assessment.

Discussion

The evaluation reported here demonstrated that information amount and relevance significantly affected the performance of participant platoon leaders using a future automated C^2 system. Although an initial investigation, a number of key findings emerged that should provide a better understanding of how such systems might be used and what training requirements need to be addressed by future information management training programs. These findings are discussed in greater detail throughout this section but a consolidated preview may be useful.

The higher volume of information anticipated with future C^2 systems may have serious consequences on information flow and utility. In this evaluation, high information load resulted in reduced awareness of battlefield space and the loss of appropriate information to platoon leaders' superiors and subordinates. More specifically, high amount participants were less accurate in their knowledge of reported enemy and friendly locations, and messages that should have been relayed were not. On the other hand, low amount participants relayed too much information.

Information relevance had very pronounced effects on information management performance. Less relevant information disrupted the flow of communication, promoted inappropriate relays and impaired participants' ability to accurately "see" their battlefield situation. More specifically, it took participants more time to read and relay low relevance information and its reception caused significantly more message deletion activity. Low relevance information resulted in inappropriate relays to superiors and subordinates and less accurate comprehension and projection of the platoon leader's battlefield situation.

In addition, the results indicated that vehicle-based commanders should selectively filter information they receive. By restricting relays to more appropriate messages, commanders can reduce the information load on their superiors and subordinates. Information relevance, based on proximity, proved to be an important consideration in reducing the information management requirements of the platoon leader, his superiors and his subordinates.

Preference for automated C^2 systems over voice communications for assisting platoon leaders in the performance of important command, control and communication functions was strongly evidenced. In general, high amount participants were more successful than expected at managing higher volumes of information. Their performance may show the promise of automated C^2 systems to distribute and display battlefield information rapidly and accurately. The requirement for complementary digital and voice systems was reinforced. Findings related to the improvement of automated C^2 systems are identified, particularly their potential for eliminating irrelevant communications to reduce the amount of information to be managed.

Several important training issues associated with future C^2 systems are identified based on participant performance and assessment. Finally, the method developed for standardizing and manipulating information amount and relevance for information management exercises appeared successful. Recommendations for improvement and transfer of this method to other settings including tank-based automated C^2 systems are made.

Group Equivalence

Results on the success of random assignment for the two amount conditions indicated that differences reported are not dependent on prior differences on the biographical measures tested. In addition, the participant platoon leaders concurrence with SME company commanders on relay ratings indicated they correctly understood the platoon leader information processing requirements for the messages employed in the information management exercises.

Learning-curve data was not obtained and the effect of extended training and experience on a system as innovative as the CCD should be investigated. In this evaluation, "practice" effects over the four information management exercises were minimal and the exercises were counterbalanced. Recall, that participants received approximately four hours of training in preparation for the test exercises. However, the extended training afforded by fielded automated C^2 systems might significantly affect information management performance.

Despite their concurrence with company commanders, the limited background of the platoon leader participants restricts generalization of the results to the population of experienced platoon leaders. The literature on novice versus expert performance, particularly in information processing contexts, has consistently demonstrated significant differences in skills, strategies and performance (e.g., Lord and Maher, 1991). Future research should address the information management performance of novice versus expert platoon leaders. The present results are more indicative of the automated C^2 training and performance issues associated with novice platoon leaders, a condition all-too-common on the battlefield.

Message Processing Accuracy

Results on message processing accuracy identified likely problems in managing information with automated C^2 systems. In particular, accuracy data on relay performance versus ratings suggested the perceived "value" of information is relative to information load and that load determines the type of relay errors made. More specifically, when fewer messages are received more of them are inappropriately relayed and when more messages are received too few of them are relayed. Errors in relaying information, particularly over relays, are compounded when low relevance information is received.

Although the simulated operational setting was designed to include stressors associated with the "pace of operations" and the need to maintain situational awareness, many other stressors associated with actual tactical performance were not simulated. Percentages reported on inaccurate relays may, therefore, underestimate message processing errors.

However, the data on inaccurate relay decisions indicated that overall platoon leaders inappropriately relayed 22.4% of the messages tested, based on company commander relay ratings. In the most extreme case, low amount participants and low relevance information, participants inappropriately relayed more than one-third of the messages received. This tendency to over relay battlefield information when equipped with an automated C^2 system is a valid concern. Even experienced tactical commanders using such systems relay too many reports including multiple relays of

the same report to the same receivers (Ainslie et al., 1991; Du Bois & Smith, 1991).

These results on relay accuracy indicate that information management training for future automated C^2 systems may be required to ensure battlefield information is appropriately disseminated. As these systems are fielded, commanders and units will have the opportunity to develop standardized information management procedures that may result in more accurate message distribution. Nevertheless, information management training for automated C^2 systems should address the demonstrated potential of such systems for mismanagement and increased information load.

An additional measure of message processing accuracy was selection of the correct combat net for message relay. While data on net selection errors with conventional voice-based communication systems are wanting, admonishments such as "you're on the wrong net" are common even in simulated battlefield settings. The transition from conventional voice-based C^2 systems to an electronic information delivery system marks a significant departure in communication procedures. With voice-based systems users provide identifying call signs at the start of each communication and identities are continuously reinforced by auditory cues.

The data on net selection clearly indicated that platoon leaders relied on the CCD's default routing mechanism. When the default net was wrong, they accepted the incorrect net one-fourth of the time. With the dual-net structure available to most vehicle-based commanders such incorrect routing would result in relay of the same message back to its source, contributing to the receiver's information load. Data were not obtained on net selection errors for C^2 systems without automatic net selection. Manual, or nonautomated selection, however, might result in more errors and slower message relays.

These findings on net selection errors have resulted in several modifications to the CCD's design that might be adopted for future automated C^2 systems. The CCD's default routing mechanism was revised to alternate net selection for messages relayed; and routing cues, such as sender and originator identifiers, were provided on the CCD's Report Action Menu (Lavine et al., 1993). Design modifications, such as the elimination of duplicate reports, might partially counter net selection errors. Information management training programs, however, should address the demonstrated potential for net selection errors on future automated C^2 systems.

Message Processing Speed

Results on message processing speed indicated some potential problems in managing information with automated C^2 systems. For example, high amount participants took less time to read messages

and that may account for their errors in distributing and encoding information. Reception of low relevance messages slowed the processing of information as evidenced by extended read and relay times. Although time to open and relay messages did not differ by amount, as tested, further research in a multi-task environment is recommended.

Processing times reported for this evaluation reflect the limited operational requirements simulated and indicate relative differences between the conditions tested. Relation of the times obtained to actual battlefield performance is discouraged. Nevertheless, the requirement to manage battlefield information rapidly is critical. Platoon leaders in the high amount condition took, on the average, five additional seconds to open their messages. On the battlefield, five-second delays may have very significant consequences.

The more variable opening times for the high amount condition indicated some participants had difficulty in "keeping up" with high information loads. Overall, participants quickly adjusted to the fixed-interval transmission schedule. For low amount participants, their schedule seemed to provide ample time for completion of message processing prior to reception of the next message. Whenever possible, high amount participants appeared to adopt a "can do" mentality that allocated message processing requirements to time available prior to the next message. As indicated by their high variability on message opening times, however, high amount participants were frequently unable to complete all message processing before the next message arrived.

A fixed-interval transmission schedule does not realistically reflect the message processing requirements on a battlefield. Clearly, future research should address the effects of variable-interval schedules on such requirements. Although not adopted for prototype development of the information management exercise method, variable-interval software routines can be developed on the SEND utility.

Similarly, commanders in full-mission scenarios have many tasks and concerns that compete with information management and, in particular, message opening times. In a simulated defensive scenario, for example, CCD-equipped commanders' average median opening times ranged from 23 to 72 seconds across the Contact, Spot and Intelligence report types (Leibrecht, 1992) included in this evaluation. These full-mission opening times reflect the many requirements on a battlefield commander including direct-fire engagements. In contrast, the delay-in-sector segment used for initial development of the information management exercises targeted a post-engagement phase of operation that realistically elevates a commander's information management requirements.

Information amount and relevance significantly affected the "read" times for messages relayed. High amount participants spent less time on the message processing activities underlying

read time including comprehension, note-taking and relay decisions. Faster read times by the high amount participants may account for their errors in not relaying messages they should have and their difficulty in plotting reported enemy and friendly locations.

Relay time data suggested that high amount participants were generally able to disseminate battlefield information as rapidly as the low amount condition. On occasion, however, higher information load appeared to cause significant delays in message relays as indicated by the greater variability of the high amount condition. Relay times in a multi-task setting, however, might demonstrate that more information impedes communication flow and that training strategies for reducing information load are required.

Message Processing Actions

Type of actions taken on messages differed significantly as a function of information amount and relevance. As with message processing accuracy, data on the frequency of message relay and deletion indicated the "value" of information is relative to its load. More specifically, low amount participants relayed more messages and deleted fewer. Given the very discrepant actions taken by low versus high amount participants on identical messages, the effect of information amount on information management performance was striking.

An alternate explanation for these discrepancies is that the additional messages received by the high amount condition provided information redundant to the common subset of nine messages. However, the development of message sets for this initial evaluation was directed by a deliberate decision to avoid duplicate messages, redundant information and disinformation. Armor SMEs who developed the message sets conscientiously attempted to abide with that decision.

A substantive distinction between common set and additional messages was their respective provision of information on the enemy's main unit versus supporting subunits. To ensure a comprehensive description of each battlefield situation in a set of nine messages, the common set addressed more global aspects of the situation, particularly the activities of the enemy's main unit. Additional messages received by high amount participants generally provided information on subunits acting in accordance with the main unit's attack. A reduction in the relay of subunit information, given main unit reports, might be expected. But reported differences on message processing actions are based only on common set messages, essentially main unit information.

The authors support the interpretation that the reported effects of information amount on relay and deletion are not due to information redundancy and the content of all message sets is available for review (Appendix B). Depending on training or

evaluation objectives, future efforts on information management might investigate the effects of duplicate messages, redundant information and disinformation. Such communications are common on the battlefield.

Information relevance effects on actions taken demonstrated that messages from the high relevance sets were more frequently relayed and less likely to be deleted. In fact, no messages from the high relevance message sets were deleted by participants in the low amount condition. Similarly, messages from the high relevance message sets were less likely to receive no action. The results strongly suggest that information relevance is a critical factor in future efforts to reduce information management requirements.

The prospect of automated C^2 systems swamping vehicle-based commanders in a flood of information, particularly irrelevant information, is a primary concern. Future front-end analyses on message routing and filtering for such systems must consider more than message type and source. The findings on relay and deletion actions demonstrated that information relevance has significant effects on information management and that parent unit's sector (e.g., company) is an effective basis for defining relevance.

In addition to proximity, other factors that might be included in considerations of relevance are the size, alignment, type and heading of the reported unit. Training issues aside, design modifications in automated C^2 systems might employ automated relays and message filtering based on these relevance factors to reduce the information management requirements of future vehicle-based commanders.

Based on the Relay To versus Relay By rating comparisons, the echelon of a receiver also clearly affects information relevance. Recall, these comparisons indicated significantly more of the same messages were appropriate for platoon leader's reception than his relay, particularly for low relevance message sets. Training programs on information management should stress information relevance (see Winsch et al., in preparation) and ensure that communicator's understanding of information requirements is evidenced in performance.

Limited use of the Old Files was consistent with the relatively brief duration of the information management exercises and the absence of competing task requirements. Old Files were used exclusively by the low amount participants and primarily for "policing" their CCD's via message deletions. The ability of high amount participants to delete messages "on the fly" from the Receive Queue was clearly evident. The disposal of unnecessary messages is an important requirement for managing information effectively, particularly with the provision of digital copies by automated C^2 systems. Information can become obsolete quickly on a dynamic battlefield.

Situational Awareness

Results on situational awareness were mixed but informative. Higher amounts of information impaired the platoon leader's ability to plot reported enemy and friendly locations. This ability is fundamental to a combatant's understanding of the battlefield space constraints on and opportunities for maneuver and engagement. Additionally, less relevant information reduced comprehension and projection of the platoon leader's battlefield situation.

As evidenced by "read" time differences, low amount participants spent significantly more time reading and taking notes on messages received. Perhaps, this extra time enabled them to encode the reported locations more accurately. The less accurate plotting performance by high amount participants might also be attributed to interference from additional messages and locations. Contrary to expectation, plotting performance on high relevance message sets was no better than that for low relevance sets.

No predictions were made on differences between current and future battlefield situation performance and no such differences were detected. A trend for more accurate plotting on the future battlefield situation was apparent. Given the delay-in-sector vignette used, greater concern with the future situation seems reasonable. Reported locations for this situation included obstacles and enemy units that might directly impact displacement to the subsequent battle position. In contrast, many of the current situation reports conveyed less threatening information summarizing enemy units destroyed or damaged.

Participants' ability to "see" the battlefield was not significantly affected by information amount, as tested. In contrast to the discrete locations required for plotting, the questions developed to measure seeing performance were assimilative. They required participants to consolidate information across messages. Though unintended, the additional (to the common set) messages received by the high amount participants may have reinforced their comprehension and projection of the battlefield situation. These additional messages provided high amount participants auxiliary information such as enemy subunits' location and heading that may have contributed to their understanding of the main unit's force structure and intent.

Information relevance significantly affected platoon leaders' seeing performance. Less relevant information reduced their ability to comprehend the battlefield situation and their ability to project how the information reported might impact the future battlefield situation. These results suggest reduction in low relevance information would aid the platoon leader's ability to see the battlefield.

Ancillary Measures

Self-ratings on situational awareness and workload were indifferent to information amount and relevance. Information amount effects, in particular, should be reassessed as a within subjects factor.

Ratings on the assistance provided by conventional voice versus digital, or CCD, communication systems for selected command, control and communication functions were highly discriminate. Voice radio was strongly preferred for "expressing message urgency" and "receiving feedback on messages received." Most participants also rated the voice mode better for "keeping your eyes on the battlefield."

On the other hand, participant ratings indicated the CCD provides significantly more assistance than voice radio for 9 of the 13 functions assessed. The importance ratings associated with these CCD preferred functions indicated the participants perceived them as "Very Important" to "Extremely Important." These results indicated limitations with current voice-based communications and the need for complementary voice and digital modes to support important command, control and communication functions.

Method Checks on Information Management Exercises

Checks on information amount and relevance indicated the information management exercises successfully manipulated these variables in a simulated operational setting. As noted, the manipulation of information amount was dependent on software routines developed for delivery of the information management exercises. Successful checks on these routines included information amount, rate of transmission, net "bleedover" and simultaneous transmission of message sets in counterbalanced order.

The manipulation of information relevance based on company sector also appeared successful. While objective data on platoon leader information management demonstrated relevance effects, the subjective data on relay ratings may be of special interest. This rating data was obtained from both company commanders and platoon leaders in a nonoperational setting expected to reduce rating error. For both Relay To and Relay By categories, comparisons demonstrated significantly lower information requirements for low relevance message sets.

The relay rating data also reinforced the evaluation's concern with the information management requirement to reduce information load. Significantly higher ratings by platoon leaders and company commanders on Relay To versus Relay By ratings underscore the need for tactical commanders such as platoon leaders to filter battlefield communications. The

differences obtained forcefully demonstrated the receiver's requirement to relay information selectively.

In conclusion, results on the manipulation checks are encouraging as methods for rapidly generating and varying information amount and relevance may be useful for future C^2 training and assessment efforts. To support such efforts, the software routines and message files developed for this evaluation are documented (Lickteig, 1991) and resident in the MWTB's SEND utility. The information management exercise method can be transferred to other simulation-based training and assessment environments such as the Mounted Warfare Simulation Training Center at Fort Knox or the proposed Close Combat Tactical Trainer (CCTT), currently under development. Given the computer-based nature of automated C^2 systems, similar exercises could be adapted for embedded training on operational equipment.

Conclusions

The evaluation demonstrated that information amount and relevance had significant effects on the information management performance of platoon leaders equipped with automated C^2 systems. Higher amounts of information reduced the platoon leader's awareness of battlefield space and resulted in the loss of appropriate information to superiors and subordinates. The volume of messages received also affected the perceived "value" of information as indicated by the type of relay errors made.

Less relevant information disrupted the flow of communication, promoted inappropriate relays and impaired participants' ability to "see" their battlefield situation. Information relevance, based on proximity to the parent unit, reduced the information management requirements of the platoon leader, his superiors and his subordinates.

The ability of automated C^2 systems to assist platoon leaders in the performance of key command, control and communication functions was evidenced by participant performance and assessment. High amount participants were more successful than expected at managing higher volumes of information. Their performance may support the potential of automated C^2 systems to distribute and display battlefield information rapidly and accurately. Participants preferred automated C^2 systems over conventional voice-based communication systems for a variety of command, control and communication functions rated as very important. Shortcomings with conventional voice communications were identified and the need for complementary digital and voice systems was reinforced.

A conventional voice condition was not included in the evaluation. However, informal assessments have indicated that when using voice radio and proper authentication and "break" procedures, platoon leaders could not even receive the 21

messages included in the high amount condition in the 10-minute exercise interval. Subsequent relay of the information, an information management requirement met by the participants, might require an equivalent amount of time using voice-based communication systems. These informal assessments did not attempt to measure the accuracy of voice relays for the subject message sets. Formal evaluations, however, have repeatedly demonstrated that voice communications are significantly less accurate than digital battlefield reporting (Leibrecht et al., 1992; O'Brien et al., 1992).

Numerous issues related to the training and assessment of information management with automated C^2 systems were identified. Training programs must address the demonstrated potential of such systems for information overload and mismanagement. Particular concerns are the effects of information amount and relevance on relay errors and information processing speed. Training programs should stress the receiver's responsibility to filter information and how consideration of information relevance might reduce information load on superiors and subordinates.

Limitations in the evaluation and the prototype method developed for providing information management exercises were recognized. Future modifications to the method might address validity issues such as variable-interval transmission schedules, misleading and redundant information, and a multi-task environment. For greater generalization, method modifications might include other command and staff duty positions, different missions and all mission phases--planning, preparation, execution.

As demonstrated, the method developed for delivering information management exercises provides an effective and efficient approach for rapidly generating battlefield conditions and information flow to enable future commanders to hone their information management skills. The method's use of surrogate communicators could substantially reduce personnel and equipment requirements for information management training. This method can be adapted for other training settings and embedded in future C^2 systems.

Finally, this method for delivery and manipulation of information management exercises should enable trainers to tailor training programs for managing battlefield information. The ability to customize training supports the sometimes conflicting requirements for soldier, leader, staff and unit readiness in active and reserve component forces. Such readiness may be required to win the "information war" on the future battlefield.

REFERENCES

Ainslie, F. M., Leibrecht, B. C., & Kerins, J. W. (1992). Combat vehicle command and control systems: III. Simulation-based evaluation of soldier-machine-interface (ARI Technical Report 944). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A246 237)

Alluisi, E. A. (1991). The development of technology for collective training: SIMNET, a case history. Human factors, 33(3), 343-362.

Atwood, N. K., Quinkert, K. A., Campbell, M. R., Lameier, K. F., Leibrecht, B. C., & Doherty, W. J. (1991). Combat vehicle command and control systems: IV. Training implications based on company level simulation (ARI Technical Report 943). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A246 460)

Baker, J. D. (1970). Quantitative modeling of human performance in information systems. Ergonomics, 13, 645-664.

Baker, R. A., Cook, J. G., Warnick, W. L., & Robinson, J. P. (1964). Development and evaluation of systems for the conduct of tactical training at the tank platoon level (ARI Technical Report 88). Fort Knox, KY: U.S. Army Armor Human Research Unit.

Barron, R. C., Lutz, W. G., Degelo, G. J., Havens, J. W., Talley, J. W., Smith, J. R., & Walter, R. F. (1976). Degradation of tank effectiveness (TCATA Test Report Field Manual 325). Fort Hood, TX: Headquarters, TRADOC Combined Arms Test Activity.

Burkett, J. (1991, November). Tactical information: What you see is what you get. Military Review, pp. 39-44.

Chung, J. W., Dickens, A. R., O'Toole, B. P., & Chiang, C. J. (1987). SIMNET M1 Abrams main battle tank simulation: Software description and documentation (BBN Report 6323). Cambridge, MA: Bolt, Beranek, and Newman Laboratories, Inc.

Crumley, L. M. (1989). Review of research and methodologies relevant to Army command and control performance requirements (ARI Technical Report 825). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A211 247)

Department of the Army (1990). TRADOC Pamphlet 11-9: Blueprint of the battlefield. Fort Monroe, VA: U.S. Army Training and Doctrine Command.

Department of the Army (1988). Mission training plan for the tank platoon (ARTEP 17-237-10 MTP). Washington, DC. (Available from the Commander, U.S. Army Armor Center and Fort Knox, ATTN: ATZK-DS, Fort Knox, KY 40121-5200)

Department of the Army (1985). Battalion and brigade command and control (Field Circular 71-6). Fort Knox, KY: U.S. Army Armor Center.

Drucker, E. H., & Morrison, J. E. (1987). The development of single tank tactical exercise for training M1 tank commanders (ARI Research Report 1443). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A189 482)

Drucker, E. H., & O'Brien, R. E. (1982). Mission-based analyses of armor training requirements. Volume I: Final report (ARI Research Product 82-10). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A166 253)

Du Bois, R. S., & Smith, P. G. (1991). Simulation-based assessment of automated command, control, and communication for armor crews and platoons: The intervehicular information system (IVIS) (ARI Technical Report 918). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A233 509)

Du Bois, R. S. & Smith, P. G. (1990). Simulation-based command, control, and communication exercise for armor small unit commanders (ARI Technical Report 866). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A218 869)

Emery, C. D., & Lickteig, C. W. (1991). Training on future C^2 systems: Platoon leader information requirements. Proceedings of the 33rd Annual Conference of the Military Testing Association, 33, 743-748.

Endsley, M. R. (1988). Situation awareness in aircraft systems. Proceedings of the Human Factors Society-32nd Annual Meeting, 1, 96-101. Santa Monica, CA: The Human Factors Society.

Foley, T. C. (1991, Nov-Dec). An armored force for the future 2000 and beyond--technology (Part II). Armor, pp. 406.

Foss, J. W. (1991, February). Advent of the nonlinear battlefield: AirLand battle-future. Army, pp. 20-37.

Fracker, M. L. (1988). A theory of situation assessment: Implications for measuring situation awareness. Proceedings of the Human Factors Society-32nd Annual Meeting, 1, 102-115. Santa Monica, CA: The Human Factors Society.

Giboney, T. B. (1991, November). Commander's control from information chaos. Military Review, pp. 34-38.

Goldstein, I. L. (1991). Training in work organizations. In M. D. Dunnette & L. M. Hough (Eds.), Handbook of Industrial and Organizational Psychology (Vol. 2, Chapter 9, pp. 507-619). Palo Alto, CA: Consulting Psychologists Press Inc.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), Human Mental Workload (pp. 139-183). Amsterdam: North Holland.

Kaplan, I. T. (1987). Lessons learned in research on command group training (ARI Technical Report 751). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A186 996)

Kaplan, I. T. (1980). Information flow in battalion command groups (ARI Technical Report 499). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A109 469)

Kerns, K. (1991). Blending voice and data link for improved air traffic control communications: Implications of simulation research. Human Factors Society Bulletin, 34(9), 1-4.

LaVine, N. D., Lickteig, C. W., & Schmidt, J. H. (1993). Description of a tank-based automated command and control system as simulated for the combat vehicle command and control program (ARI Research Product 93-02). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A263 459)

Leibrecht, B. C., Kerins, J. W., & Ainslie, F. M., Sawyer, A. R., Childs, J. M., & Doherty, W. J. (1992). Combat vehicle command and control systems: I. Simulation-based company level evaluation (ARI Technical Report 950). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A251 917)

Lickteig, C. W. (1991). Prototype methods for training and assessing future tactical command and control skills (ARI Research Product 92-01). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A244 328)

Lord, R. G., & Maher, K. J. (1991). Cognitive theory in industrial and organizational psychology. In M. D. Dunnette & L. M. Hough (Eds.), Handbook of Industrial and Organizational Psychology (Vol. 2, Chapter 1, pp. 1-62). Palo Alto, CA: Consulting Psychologists Press Inc.

Morey, J. C., Wigginton, D., & O'Brien, L. H. (1992). Workload assessment for the combat vehicle command and control company-level evaluation (ARI Research Report 1615). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A252 239)

Norusis, M. J. (1988). SPSS/PC+ Advanced Statistics V3.0. Chicago: SPSS, Inc.

O'Brien, L. H., Wigginton, D., Morey, J. C., Leibrecht, B. C., Ainslie, F. M., & Sawyer, A. R. (1992). Combat vehicle command and control battalion-level preliminary evaluation (ARI Research Report 1627). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A257 467)

O'Brien, R. E. (1986). Training armor skills: The development of tactical leadership exercises for SIMCAT (ARI Research Note 87-38). Alexandria, VA: Human Resources Research Organization.

Olmstead, J. A., Christensen, H. E., & Lackey, L. L. (1973). Components of organizational competence: Test of a conceptual framework (HumRRO TR-73-19). Alexandria, VA: Human Resources Research Organization.

Palmer, R. L. (1992). C^3I test-instrumentation system: MANPRINT evaluation of the data collection system (ARI Research Report 1619). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A252 655)

Phelps, R. O., & Kupets, G. (1984). U.S. Army Human Engineering Laboratory Communications Survey--A pilot study (HELCOMS-PS) (Technical Notes 14-84). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Pope, A. R. (1987). The SIMNET network and protocol (BBN Report 6309). Cambridge, MA: Bolt, Beranek, and Newman Laboratories, Inc.

Sarter, N. B., & Woods, D. D. (1991). Situation awareness: A critical but ill-defined phenomenon. International Journal of Aviation Psychology, I(1), 45-47.

Schwartz, S., & Floyd, J. A. (1963). Improving tactical training for tank commanders: Test development and performance assessment (Technical Report 82). Fort Knox, KY: U.S. Army Armor Human Research Unit.

Shoffner, W. A. (1993, March). Future battlefield dynamics and complexities require timely and relevant information. PHALANX, pp. 1-35.

Siegel, A. I., Wolf, J. J., Leahy, W. R., & Bearde, J. L. (1977). A digital simulation model of message handling in the tactical operations system: II. Extensions of the model for interactivity with subjects and experimenters. TR-77-A23 and A-24. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A047 104; AD A046 407)

Solick, R. E., & Lussier, J. W. (1988). Design of battle simulations for command and staff training (ARI Technical Report 788). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A190 855)

U.S. Army Armor Center (1992). IVIS operational concept (ATZK-CD). Fort Knox, KY: U.S. Army Armor Center, Directorate of Combat Developments.

Whitehurst, G. J. (1984). Interrater agreement for journal manuscript reviews. American Psychologist, 39(1), 22-28.

Winsch, B. J., Atwood, N. K., Sawyer, A. R., Heiden, C. K., Smith, P. G., & Schwartz, N. (in preparation). Innovative training concepts for use in distributed interactive simulation environments. (ARI Research Product). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Word, L. E. (1987). Observations from three years at the National Training Center (ARI Research Product 87-02). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A178 300)

APPENDIX A

SAMPLE CONTROLLER'S LOG

Controller's Log for Information Management Exercises

Controller, this schedule for participants 13-16 designates by session and participant (#) number: simulator ID, information relevance level, simulator location, and the counterbalanced order of SEND files for information management exercises and overlays as well as support staff's administration of situational awareness questionnaires.
Low Information Amount (LA)

Sess	#s Sim	#s #s	C² Ex OPORD	Relv Level	Sim Loc	FRAGO Overlay	SA Sea	SA Plot
P	2B	13	P	M	C	C	2	2
A	2B	13	1	L	A	A	1	1
B	2B	13	4	H	B	B	2	2
C	2B	13	2	H	A	A	1	1
D	2B	13	3	L	B	B	2	2
P	3B	14	P	M	C	C	1	1
A	3B	14	3	L	B	B	2	2
B	3B	14	2	H	A	A	1	1
C	3B	14	4	H	B	B	2	2
D	3B	14	1	L	A	A	1	1
P	4A	15	P	M	C	C	1	1
A	4A	15	2	H	A	A	2	2
B	4A	15	3	L	B	B	1	1
C	4A	15	1	L	A	A	2	2
D	4A	15	4	H	B	B	1	1
P	4B	16	P	M	C	C	2	2
A	4B	16	4	H	B	B	1	1
B	4B	16	1	L	A	A	2	2
C	4B	16	3	L	B	B	1	1
D	4B	16	2	H	A	A	2	2

Session: Session = Practice, Alpha (LR_1), Bravo (HR_1), Charley (LR_2), Delta (HR_2)
Amount: Low = 9; High = 21
Relevance: Low = Vign OPORD 1+3; High = Vign 2+4
Situation: A = Mission A, Location A (MA,LA); B = MB,LB; C = Mission C, Location C (MC,LC)
Location: A = BP 123, ES838875; B = BP 121, ES879797; C = BP 122, ES865864

APPENDIX B

TEST MESSAGE SETS FOR PLATOON LEADERS

Message Sets for Vignette 1: Low Relevance, Location A[a]

Type	L[b]	From	What	Number/State Obs	Dam	Des	Where[a]	Dir	Activity En	Fr	As Of
Spot	L	A23	En Tnk		3	17	822867		Atk	Def	Now
Intel		DO6	Fr Mech	4			791892			Def	-5
Spot		DO6	En Tnk		2	8	799838	10	Atk	Def	Now
Spot	L	DO6	En Tnk		4	10	820831	8	Atk	Def	Now
Intel		YO2	En PC	1			883890		Rec		-20
Intel		YO2	Fr Supt	4			794915			Def	-5
Spot	L	DO6	En Tnk		0	10	809841	1	Atk	Def	Now
Intel	L	AO6	Mine	0			805911[c]				-20
Cont		A22	En FW	nr			832840				
Intel		YO2	En PC	2			785889	10	Rec		-5
Intel	L	YO2	En Tnk	31			836844	30	Atk		-5
Cont	L	DO6	En Tnk	nr			834829				
Intel		DO6	Mine	0			794874[c]				-20
Intel		YO2	Fr Sct	2			859845			Rec	-20
Spot		A24	En PC		0	2	820898		Rec	Def	Now
Intel		YO2	En Trck	2			839908	300		Def	-20
Cont		A22	En Helo	nr			842840				
Cont	L	A22	En Tnk	nr			825860				
Intel		YO2	Fr Mort	4			830900			Def	-20
Intel	L	YO2	En PC	10			829811	340	Atk		-20
Intel	L	YO2	En PC	10			821811	34	Atk		-20

Note. Obs = observed; Dam = damaged; Des = destroyed; Dir = direction; En = enemy; Fr = friendly; As Of = minutes; PC = personnel carrier; Sct = scout; Trp = troops; Helo = helicopter; Trck = truck; C^2 = command and control; Mech = mechanized infantry; Mort = mortar; FW = fixed wing air; Tnk = tank; ATGM = anti-tank guided missile; Supt = support; Atk = ground attack; Aatk = air attack; Def = defend; Rec = reconnaissance; Art = artillery; Bln Bdg = blown bridge; nr = not reported.

[a] Own location = ES838875. All other map locations have ES prefix.

[b] L = messages used in low amount (LA) set. All messages listed in order presented.

[c] Minefield and ditch locations equal center of mass, but commanders received coordinates for each endpoint.

Message Sets for Vignette 2: High Relevance, Location A[a]

Type	L[b]	From	What	Number/State Obs	Dam	Des	Where[a]	Dir	Activity En	Fr	As Of
Spot	L	A23	En Tnk		5	15	851864		Atk	Def	Now
Cont		A23	En Tnk	nr			853876				
Spot		A22	En Tnk		1	2	842872		Atk	Def	Now
Intel		YO2	En PC	10			839825	315	Atk		-20
Spot		A23	En Tnk		1	4	850875		Atk	Def	Now
Intel	L	YO2	Fr Mort	4			850911			Def	-20
Intel	L	YO2	Fr Sct	2			836841			Rec	-20
Cont		YO6	En Helo	nr			871841				
Intel		YO2	En Trck	2			795928	315		Def	-5
Spot	L	A24	En PC		0	2	840891		Rec	Def	Now
Intel	L	YO2	En Tnk	31			871836		Atk		-5
Intel		YO6	En PC	10			839831	315	Atk		-20
Intel	L	AO6	Mine	0			828927[c]				-20
Cont		A22	En Trp	nr			834849				
Cont	L	A22	En Helo	nr			864874				
Intel	L	YO2	En Tnk	31			861841	345	Atk		-5
Intel	L	AO6	Mine	0			813896[c]				-20
Intel		YO2	En Art	8			873829		Atk		-20
Cont		A24	En FW	nr			855834				
Spot		A22	En Tnk		0	1	832882		Atk	Def	Now
Intel		YO2	Fr C[2]				812918			Def	-5

Note: Obs = observed; Dam = damaged; Des = destroyed; Dir = direction; En = enemy; Fr = friendly; As Of = minutes; PC = personnel carrier; Sct = scout; Trp = troops; Helo = helicopter; Trck = truck; C[2] = command and control; Mech = mechanized infantry; Mort = mortar; FW = fixed wing air; Tnk = tank; ATGM = anti-tank guided missile; Supt = support; Atk = ground attack; AAtk = air attack; Def = defend; Rec = reconnaissance; Art = artillery; Bln Bdg = blown bridge; nr = not reported.

[a] Own location = AA838878. All other map locations have AA prefix.

[b] L = messages used in low amount (LA) set. All messages listed in order presented.

[c] Minefield and ditch locations equal center of mass, but commanders received coordinates for each endpoint.

Message Sets for Vignette 3: Low Relevance, Location B[a]

Type	L[b]	From	What	Number/State Obs	Dam	Des	Where[a]	Dir	Activity En	Fr	As Of
Intel	L	YO2	En PC	35			918775	275	Atk		-20
Cont	L	CO6	En PC	nr			940778				
Spot	L	CO6	En PC		2	5	962798	300	Atk	Def	Now
Intel		YO2	Fr Sct	2			912765			Rec	-20
Intel		CO6	En Trp	4			951850	300	Rec		-20
Cont		A22	En Helo	nr			872752				
Intel		YO2	Fr C^2	3			891851			Def	-5
Spot	L	A23	En PC		5	15	892781		Atk	Def	Now
Intel	L	YO2	Fr Mech	4			935805			Def	-5
Intel	L	YO2	En PC	2			898850	310	Rec		-20
Spot		A24	En PC		0	2	892825		Rec	Def	Now
Cont		DO6	En PC	nr			838749				
Intel		YO2	Fr Mort	4			883818			Def	-20
Intel		YO2	En FW	2			810801	310	AAtk		-20
Intel	L	AO6	Mine	0			867806[c]				-20
Intel	L	YO2	En PC	20			940788	300	Atk		-5
Intel	L	YO2	En ATGM	4			944792	1	Atk		-5
Intel		YO2	Fr Supt	4			885895	350		Def	-20
Spot		YO2	En ATGM		0	4	945800		Atk	Def	Now
Intel		DO6	En PC	10			899783			Def	-5
Spot		DO6	En PC		0	2	835755		Rec	Def	Now

Note. Obs = observed; Dam = damaged; Des = destroyed; Dir = direction; En = enemy; Fr = friendly; As Of = minutes; PC = personnel carrier; Sct = scout; Trp = troops; Helo = helicopter; Trck = truck; C^2 = command and control; Mech = mechanized infantry; Mort = mortar; FW = fixed wing air; Tnk = tank; ATGM = anti-tank guided missile; Supt = support; Atk = ground attack; AAtk = air attack; Def = defend; Rec = reconnaissance; Art = artillery; Bln Bdg = blown bridge; nr = not reported.

[a] Own location = ES8878797. All other map locations have ES prefix.

[b] L = messages used in low amount (LA) set. All messages listed in order presented.

[c] Minefield and ditch locations equal center of mass, but commanders received coordinates for each endpoint.

Message Sets for Vignette 4: High Relevance, Location B[a]

Type	L[b]	From	What	Number/State Obs	Dam	Des	Where[c]	Dir	Activity En	Fr	As Of
Intel	L	YO2	Mine	0			868807[c]				-20
Spot		A23	En PC		3	7	885788		Atk	Def	Now
Intel	L	YO2	Fr Mort	4			864824			Def	-20
Intel	L	YO2	En PC	35			881755	10	Atk		-5
Intel		A06	Ditch	0			846820[c]				-20
Intel		YO2	En PC	1			882741	290	Rec		-20
Cont		YO6	En ATGM	nr			902771				
Spot	L	A24	En PC		0	2	871824		Rec	Def	Now
Intel	L	YO2	Fr Sct	2			895765			Rec	-20
Intel		A23	En Trp	6			887784	180	Atk		-20
Spot		A24	En PC		0	4	881782		Atk	Def	Now
Spot	L	A23	En PC		5	15	871779		Atk	Def	Now
Spot		A22	En PC		2		881783		Atk	Def	Now
Intel		YO2	En ATGM	4			902771	300	Atk		-20
Intel	L	A06	Bln Bdg	0			870826				-20
Cont	L	A22	En Helo	nr			918769				
Spot		A24	En ATGM		1	3	892784		Atk	Def	Now
Intel		YO6	En PC	2			903780	12	Atk		-20
Intel	L	YO6	En Tnk	4			918769	50	Atk		-20
Cont		A22	En Trp	nr			884783				
Intel		YO2	En PC	10			918769	50	Atk		-20

Note. Obs = observed; Dam = damaged; Des = destroyed; Dir = direction; En = enemy; Fr = friendly; As Of = minutes; PC = personnel carrier; Sct = scout; Trp = troops; Helo = helicopter; Trck = truck; C^2 = command and control; Mech = mechanized infantry; Mort = mortar; FW = fixed wing air; Tnk = tank; ATGM = anti-tank guided missile; Supt = support; Atk = ground attack; AAtk = air attack; Def = defend; Rec = reconnaissance; Art = artillery; Bln Bdg = blown bridge; nr = not reported.

[a] Own location = ES879797. All other map locations have ES prefix.

[b] L = messages used in low amount (La) set. All messages listed in order presented.

[c] Minefield and ditch locations equal center of mass, but commanders received coordinates for each endpoint.

SITUATIONAL AWARENESS MEASURES

Situational Awareness: "Seeing" the Current Situation

The following questions ask about your awareness of the current situation. The first two questions ask about units reportedly engaged by your company. The next two questions ask about the main enemy unit reported but not engaged by your company. The final question asks your assessment of the total unit committed against the entire Task Force based on all reports received. For each item, either write your answer in the blank provided, or circle the one letter indicating the best answer.

1. Based on the reports sent to you, how many vehicles by type were damaged or destroyed in your company sector by your company? The numbers you enter should indicate the total number of vehicles by type reportedly destroyed or damaged by your company.

TYPE	NUMBER
Tank	_____
IFVs	_____
Other _____ (Specify)	_____

2. Based on the numbers and types of vehicles reported as destroyed and damaged in your company sector (question 1), estimate the size and type of enemy force your company engaged?

a. Mechanised Rifle Company (MRC)
b. Mechanised Rifle Battalion (MRB)
c. Mechanised Rifle Regiment (MRR)
d. Tank Company
e. Tank Battalion
f. Tank Regiment

3. Based on the reports sent to you, how many and what type of vehicles that were **not engaged** are still approaching to the front of your **company's** position?

TYPE	NUMBER
Tank	_____
PCs	_____
Other _____ (Specify)	_____

4. Based on the numbers and types of vehicles reported approaching your **company** position but **not engaged** (question 3), estimate what size and type of unit is still approaching?

a. Mechanized Rifle Company (MRC)
b. Mechanized Rifle Battalion (MRB)
c. Mechanized Rifle Regiment (MRR)
d. Tank Company
e. Tank Battalion
f. Tank Regiment

5. Based on all reports received, what is your estimate of the overall size and type of unit committed against the **Task Force**?

a. Mechanized Rifle Company (MRC)
b. Mechanized Rifle Battalion (MRB)
c. Mechanized Rifle Regiment (MRR)
d. Tank Company
e. Tank Battalion
f. Tank Regiment

**********FOR RESEARCHERS ONLY**********

F1(S) (1) S# _____ (2) Sim # 2B 3B 4A 4B 5th sim
(3) Vign: Practice A B C D (4) Amount: H M L
(5) Date: _____ (6) RA _____

Situational Awareness: "Seeing" the Future Situation

The following questions ask about your awareness of the future situation. The first two questions ask about the main unit reported to your company's front. The third question asks about your estimate of when that unit may reach your current vehicle's position. And the final two questions ask about the distance and direction to your company's designated subsequent battle position, and the impact reported obstacle(s) may have on your company's movement to its subsequent battle position. For each item, either write your answer in the blank provided, or circle the one letter indicating the best answer.

1. From your vehicle's current position, how far in kilometers (km) and in what direction is the **main** unit **not engaged** that is approaching your company's front?

DISTANCE (to 1/2 km) from your current position? _____km

DIRECTION (N/NE/etc) from your current position?

_____

2. HEADING (N/NE/etc.) of main unit? _____

3. Based on a speed of 10 kilometers per hour, how many minutes should it take the **main** enemy unit (question 1) to move from its reported location to within 2 kilometers of your vehicle's current position?

a. Unit will not come within 2 kilometers of my position.
b. Six minutes.
c. Twelve minutes.
d. Eighteen minutes.
e. Twenty-four minutes.

4. From your vehicle's current position, how far and in what direction is your company's subsequent battle position?

DISTANCE (to 1/2 km) from your current position? _____km

DIRECTION (N/NE/etc) from your current position? _____

5. What **impact** will the reported obstacle(s) have on your **company's movement to** or **occupation of** your designated subsequent battle position.

a. No impact.
b. The obstacle is on my designated subsequent battle position, I will have to designate a new subsequent battle position.
c. The obstacle is very close to my designated subsequent battle position. My unit will have to be careful in occupying the position.
d. The obstacle is on the primary high speed route to my designated subsequent battle position.
e. The obstacle is not on the route but will canalize my unit's movement to my designated subsequent battle position.

**********FOR RESEARCHERS ONLY**********

F2(S) (1) S# _____ (2) Sim # 2B 3B 4A 4B 5th sim
(3) Vign: Practice A B C D (4) Amount: H M L
(5) Date: _____ (6) RA _____

Situational Awareness: Plotting the Current Situation

Based on the information you received on your Command and Control Display (CCD) during this vignette, plot the locations of the items listed below on the map sheet provided. You are to plot the **actual** location as **last reported**, not a projected location such as where unit may have moved to since report reception.

As accurately as possible, for each of the items listed below:
(a) plot its location with an "X" on the map sheet, and
(b) write the item number beside the X (e.g. "X1," "X2")

On this page, below each item, indicate with an "X" on the appropriate line that you either (a) plotted the item and specified number on the map sheet, or that you did not plot the item because (b) it was not reported or provided, or (c) you can not remember its reported or provided location.

1. largest enemy unit **engaged** by your **company**
   (a) ____ plotted and numbered
   (b) ____ not plotted, not reported
   (c) ____ not plotted, can't recall location

2. largest enemy unit approaching the front of your **company** sector, but **not engaged**
   (a) ____ plotted and numbered
   (b) ____ not plotted, not reported
   (c) ____ not plotted, can't recall location

3. friendly scout unit to **front** of your **company** sector
   (a) ____ plotted and numbered
   (b) ____ not plotted, not reported
   (c) ____ not plotted, can't recall location

4. target reference points (TRPs) to **front** of your **company** sector
   (a) ____ plotted and numbered
   (b) ____ not plotted, not provided
   (c) ____ not plotted, can't recall location

5. largest enemy unit **outside** of your **company** sector
   (a) ____ plotted and numbered
   (b) ____ not plotted, not provided
   (c) ____ not plotted, can't recall location

**********FOR RESEARCHERS ONLY**********

F2(P) (1) S# _____ (2) Sim # 2B 3B 4A 4B 5th sim
(3) Vign: Practice A B C D (4) Amount: H M L
(5) Date: _____ (6) RA _____

Situational Awareness: Plotting the Future Situation

Based on the information you received on your Command and Control Display (CCD) during this vignette, plot the locations of the items listed below on the map sheet provided. You are to plot the **actual** location as **last reported**, not a projected location such as where unit may have moved to since report reception.

As accurately as possible, for each of the items listed below:
(a) plot its location with an "X" on the map sheet, and
(b) write the item number beside the X (e.g. "X1," "X2")

On this page, below each item, indicate with an "X" on the appropriate line that you either (a) plotted the item and specified number on the map sheet, or that you did not plot the item because (b) it was not reported or provided, or (c) you can not remember its reported or provided location.

1. support unit to **rear** of your **company** sector
   (a1) ____ plotted and numbered; give type (a2)_____
   (b) ____ not plotted, not reported
   (c) ____ not plotted, can't recall location

2. your **company's subsequent** battle position
   (a) ____ plotted and numbered
   (b) ____ not plotted, not provided
   (c) ____ not plotted, can't recall location

3. obstacle to **rear** of your **company** sector
   (a) ____ plotted and numbered
   (b) ____ not plotted, not provided
   (c) ____ not plotted, can't recall location

4. enemy scout unit to **rear** of your **compan.** sector
   (a) ____ plotted and numbered
   (b) ____ not plotted, not reported
   (c) ____ not plotted, can't recall location

5. friendly mortar unit in your **company** sector
   (a1) ___ plotted and numbered; give type (a2)_____
   (b) ____ not plotted, not reported
   (c) ____ not plotted, can't recall location

**********FOR RESEARCHERS ONLY**********

F1(P) (1) S# _____ (2) Sim # 2B 3B 4A 4B 5th sim
(3) Vign: Practice A B C D (4) Amount: H M L
(5) Date: _____ (6) RA _____

APPENDIX D

SCORING GUIDELINES FOR SITUATIONAL AWARENESS MEASURES

Scoring for each item based on 10-point scale: 10 = High, 6 = Medium, 2 = Low, 0 = < Low.
Summary score based on percentage of available points obtained on each form for each vignette.

Plotting Items: Form 1(P), Future Situation;
Form 2(P), Current Situation

If information provided and plotted*:

10 = .5km from exact location
6 = >.5 to 1.5km from exact location
2 = > 1.5 to 3km from exact location
0 = > 3km from exact location; reported, not plotted

* If more than one element plotted/item (e.g., more than 1 obstacle) assign equal weight for each element with total points divided by number of elements plotted.

If information not plotted, because it was not provided:
5 = "B" (not plotted, not reported)
3 = "C" (not plotted, can't recall)

If information plotted, but not provided
0 = "A" (plotted, but not provided)

If information provided, but not plotted:
0 = "B" or "C"

"Seeing" Items: Form 1(S), Current Situation

Items 1 and 3 under NUMBER for Tank and PCS are # of vehicles for each type. Scoring based on correct # reported. Allot 80% for total # of tanks and PCs reportedly engaged (.8 x # of points allotted).

10 = 90% or >
6 = 70-89%
2 = 40-69%
0 = < 40%

Items 1 and 3 under OTHER for Type and Number are # of vehicles by type other than tanks and PCs. All OTHERs, if present in the message set, together account for 20% (.2 x # of points allotted). If two "other" subtypes, weighted by .1, etc.

Scoring Guidelines for Situational Awareness, cont.

Items 1 and 3 under OTHER cont.
10 = correct type and correct number
 6 = correct type, but incorrect number
 2 = incorrect type, but correct number
 0 = incorrect type and incorrect number

"Seeing" Items: Form 1(S), Current Situation, cont.

Items 2, 4 and 5 are unit Size and Type
10 = correct echelon and type
 6 = adjacent echelon and correct type
     or correct echelon, but incorrect type
 2 = nonadjacent echelon and correct type
     or adjacent echelon and incorrect type
 0 = incorrect echelon and type

"Seeing" Items: Form 2(S), Future Situation

Items 1 and 4 Distance and Direction (Cardinal Directions (CD))
10 = 5 < .5km from exact location + 5 for correct CD
 6 = 3 > .5-1.5km from exact location + 3 for adjacent CD
 2 = 1 > 1.5 km-3km from exact location +1 for next adjacent CD
 0 = > 3km from exact location or > 90 degrees from correct CD
(Different point combinations possible)

Item 2 Heading (Cardinal Directions (CD))
10 = correct CD for direction
 6 = adjacent CD (45 degrees from correct CD)
 2 = next adjacent CD (90 degrees from correct CD)
 0 = > 90 degrees from correct CD

Item 3 Time
10 = correct
 6 = 6 minutes off
 2 = 12 minutes off
 0 = > 12 minutes off

Item 5 Obstacle Impact
10 = correct
 6 = closest option*
 2 = next closest option
 0 = other

* Options and correct answers as determined by subject matter experts (SMEs).

APPENDIX E

ANCILLARY MEASURES

Estimates of Situational Awareness & Workload

1. Provide an estimate of your situational awareness, understanding of the tactical situation, for this vignette by circling the appropriate number (1-5) below.

No Awareness		Average Awareness		Complete Awareness
1	2	3	4	5

Now we ask you to shift your attention back to the message processing phase of this vignette. Message processing included reading, filtering, and relaying messages while maintaining your own awareness of the situation. How demanding or difficult was it to perform this <u>overall</u> set of message processing tasks?

2. First, estimate the mental demand for this vignette message processing phase. How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Provide an estimate of this vignette's mental demand, overall task difficulty, by circling the appropriate number (1-5) below.

Very Low Mental Demand		Average Mental Demand		Very High Mental Demand
1	2	3	4	5

3. Second, estimate the physical demand for this vignette message processing phase. How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Provide an estimate of the physical demand you felt during this vignette's message processing phase by circling the appropriate number (1-5) below.

Very Low Physical Demand		Average Physical Demand		Very High Physical Demand
1	2	3	4	5

********** Researcher's Only **********

(1) ID _____ (2) Sim # 2A 3A 4A 4B 5th sim
(3) Vignette Practice A B C D (4) Amount: H M L
(5) Date: _____ (6) NA _____

FM RADIO vs CCD (Command and Control Display)

Duty Position: A06 A21 Subject # _____ Date _____

We would like you to compare an automated CCD versus the standard FM radio for performing the following command, control, and communication (C^3) functions. We need your assistance. For the list of C^3 functions below, you need to do three things. First, read and consider the C^3 function described.

Second, decide whether the CCD or the FM radio would provide the most assistance to you in performing that function. Then circle your answer, either CCD or RADIO, in the column **Most Assistance**.

Third, consider how important this function is to you in general, across all situations. Rate the importance of each function in the column **Importance** using the scale provided below:

Not Important 1----------2----------3----------4----------5 Extremely Important

		Most Assistance (Circle One)		Importance (Rate 1-5)
1.	Expressing message urgency	CCD	RADIO	____
2.	Ensuring standard message formats	CCD	RADIO	____
3.	Ensuring good "copy" of the message	CCD	RADIO	____
4.	Saving/recording message contents	CCD	RADIO	____
5.	Receiving feedback message received	CCD	RADIO	____
6.	Receiving operational overlays	CCD	RADIO	____
7.	Issuing FRAGO graphics	CCD	RADIO	____
8.	Linking reported locations to map locations	CCD	RADIO	____
9.	Keeping your eyes on the battlefield	CCD	RADIO	____
10.	Relaying messages received	CCD	RADIO	____
11.	Maintaining situational awareness	CCD	RADIO	____
12.	Maintaining map/overlay alignment	CCD	RADIO	____
13.	Providing easy access to map data	CCD	RADIO	____

APPENDIX F

TRAINING AND TESTING SCHEDULE

Training

7:45-8:00	Participants at training/assessment facility.
8:00-8:30	Principal Instructor presents overview brief.
8:00-8:20	Support Personnel (SP) collect materials, complete checklist to make sure they have materials needed & map boards ready. Breakdown logs put on SIMs.
8:20-8:45	Trainers/SP do SIM, CCD and radio checks. Make sure CCD is ready to receive messages before you go to Demo.
8:30-8:45	CCD introduction in classroom using slides.
8:45-9:15	Trainers present Demo on BARCO monitor. SP at Demo to provide assistance, one to take notes on participants Comments/Questions asked for training purposes.
9:15-9:25	Break
9:25-10:25	SP assigned to PLs in TOC/escort PLs out to SIM SP present Structured Hands-On Practice
10:25-10:30	Exercise set-up/Participants Break
10:30-11:05	Exercise Portion of Structured Practice for more training on message reception, relay, and retrieval.
10:30-10:35	Script on Exercise Procedure #1
10:35-10:40	PL in SIM/OPORD provided/headsets on
10:40-10:50	Practice Exercise #1 (medium amount and relevance)
10:50-11:00	Situational Awareness
11:00-11:05	Feedback with SP in SIMs
11:05-11:20	Unstructured Practice
11:20-11:25	Supervised Practice set-up/Participants break
11:25-11:45	Supervised Practice
11:25-11:30	Script for Exercise Practice #2
11:30-11:35	PL in SIM/OPORD provided/headsets on

11:35-11:45	Practice Exercise #2 (medium amount and relevance) /SP fill out checklist/No SA
11:45-12:00	Retraining with SP/Feedback
12:00-12:45	Participants Lunch
12:45-1:00	Practice Exercise Preparation
12:00-1:00	Lunch/SP in SIMs at 1:00 ready to go
1:00-1:05	Practice Exercise
1:00-1:05	Script for Exercise Practice #1
1:05-1:10	PL in SIM/OPORD provided/headsets on
1:10-1:20	Exercise Practice #1/SP fill out checklist
1:20-1:30	Situational Awareness
1:30-1:50	Questions and Answer

Testing

1:50-4:20	Session A*	
	OPORD review	5 minutes
	Message processing phase	10 minutes
	SA assessment	10 minutes
	Set-up for next exercise	5 minutes
4:20-4:50	Session B	
4:50-5:00	Break	
5:00-5:30	Session C	
5:30-6:00	Session D	
6:00-7:30	Make-ups/Preparation for next day of evaluation.	

*Session A schedule repeated for all test sessions.

APPENDIX G

SAMPLE OPORD EXTRACT

STARTING SITUATION - EXERCISE 1

Extracts from the OPORD you received last night follow this synopsis of the starting situation.

STARTING SYNOPSIS: Your unit has been in contact with the enemy for several days. Reconnaissance units probed your position extensively during the previous evening. The battalion just engaged and defeated an attacking force of unknown size and composition and are trying to discover the current situation. You (for some unknown reason) were unable to directly observe or hear any of this engagement.

You and your tank are now fully functional and are trying to gather information on the engagement to pass to your commander. You have requested your subordinate elements provide you information on the engagement. The only means of communication with your higher or lower elements is through your Command and Control Display (CCD). You may also be getting information from your higher headquarters and possibly from your adjacent units that may be of interest to your subordinate elements.

EXTRACTS FROM LAST NIGHT'S OPORD

ENEMY SITUATION: The enemy appears to be preparing to attack in sector. Intelligence has been unable to determine the size or composition of the force that may attack in sector.

FRIENDLY SITUATION:

B Company (LEFT FLANK): Defend Battle Position (BP) 22. On order, defend BP 23. (See overlay)
D Company (RIGHT FLANK): Defend BP 42. On order, defend BP 43. (See overlay)

MISSION: A Company defend BP 12. On order, defend from BP 13.

CONCEPT OF OPERATION:

1st PLT: Defend BP 113. On order, defend from BP 114.
2nd PLT: Defend BP 123. On order, defend from BP 124.
3rd PLT: Defend BP 133. On order, defend from BP 134.

SERVICE SUPPORT & COMMAND AND SIGNAL: NOT INCLUDED

APPENDIX H

SUMMARY DATA ON INFORMATION MANAGEMENT PERFORMANCE

Table H-1

Mean Percentages (and SDs) on Message Processing Accuracy by Information Amount and Relevance: Platoon Leader Relay Performance versus Company Commander Relay Ratings

Measure By Amount	Low Relevance	High Relevance
Under Relays		
Low Amount	4.17 (5.75)	3.69 (7.67)
High Amount	9.72 (11.01)	15.28 (14.47)
Over Relays		
Low Amount	34.72 (21.77)	3.69 (4.85)
High Amount	16.67 (15.71)	1.39 (3.93)

Note. Standard deviations in parentheses.

Table H-2

Mean Percentages (and SDs) on Message Processing Accuracy by Information Amount and Relevance: Platoon Leader Relay Performance versus Own Relay Ratings

Measure By Amount	Low Relevance	High Relevance
Under Relays		
Low Amount	19.44 (22.02)	8.33 (16.53)
High Amount	19.44 (18.54)	19.44 (14.24)
Over Relays		
Low Amount	61.11 (23.00)	44.44 (29.10)
High Amount	19.44 (38.38)	16.67 (25.89)

Note. Standard deviations in parentheses.

Table H-3

Mean Time (and SD) in Seconds to Process Messages Relayed from the Receive Queue by Information Amount and Relevance

Measure By Amount	Low Relevance	High Relevance
Opening Time		
Low Amount	8.67 (2.09)	7.87 (1.61)
High Amount	10.28 (9.91)	11.86 (10.09)
Read Time		
Low Amount	24.67 (5.11)	23.31 (5.52)
High Amount	17.90 (4.47)	16.78 (3.79)
Relay Time		
Low Amount	33.33 (4.60)	31.17 (5.07)
High Amount	33.16 (12.98)	28.63 (11.80)

Table H-4

Percentage Data on Receive Queue Message Processing Actions by Information Amount and Relevance

	Relayed		Deleted		Not Acted		Not Opened	
Amount	LR	HR	LR	HR	LR	HR	LR	HR
Low Amount	76.0	96.8	9.7	0.0	13.9	3.8	1.4	0.7
High Amount	83.3	81.9	34.0	13.0	11.8	4.9	0.0	0.0
Overall	84.0	89.2	21.9	6.6	12.8	3.8	0.7	0.4

Note. LR = Low Relevance, HR = High Relevance. Row totals not summing to 100% are due to rounding-up errors.

Table H-5

Mean Percentages for Plotting and Seeing Measures of Situational Awareness by Information Amount and Relevance (SDs)

Percentage	LR_1	LR_2	HR_1	HR_2
Plotting				
LA	61.6 (23.9)	54.1 (22.8)	47.1 (17.0)	45.3 (21.6)
HA	37.6 (17.2)	42.0 (15.6)	39.3 (11.4)	42.3 (16.4)
Seeing				
LA	58.5 (12.8)	61.0 (11.8)	71.0 (16.7)	83.3 (9.6)
HA	65.8 (13.5)	76.0 (12.5)	62.5 (20.0)	77.8 (13.0)

Note. LR = Low Relevance, HA = High Amount.